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JOURNAL

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ROYAL GEOLOGICAL SOCIETY OF IRELAND.

I.—ON SOME POINTS IN THE PHYSICAL GEOLOGY OF THE DINGLE AND IVERAGH PROMONTORIES, BY A. B. WYNNE, F.G.S., F.R.G.S.I., &c.

[Read March 15th, 1880.]

So many opinions have been expressed and so many conclusions arrived at regarding the complex geological relations of this part of Ireland, that there is perhaps hardly a useful consideration left to urge which has not already been debated if not already published.

Amongst these the apparently simple and natural interpretation recently advanced by Professor Hull (Q. Jour. Geo. Soc. Lon., Vol. XXXV., p. 669), that the Lower Carboniferous rocks of Iveragh were discordantly deposited upon the Dingle-Glengariff beds, can scarcely be supposed to have previously eluded the attention of the Geological Survey of Ireland, or Professor Jukes' masterly application of the logic of facts.

If the ably advanced argument of Professor Hull be considered less than imperatively conclusive, the following questions will probably need further elucidation :—

1st. Are the Carboniferous beds of Iveragh actually unconformable to the Dingle-Glengariff beds beneath them ?

2nd. Is it possible that these Lower Carboniferous beds, including the Old Red Sandstone, may be quite discordant in Dingle and quite conformable in Iveragh, to the same underlying group of the Dingle-Glengariff beds, within an area of, say 5,000 square miles.

3rd. Is this absolute unconformity necessary to the view that the Dingle-Glengariff series is of Silurian age?

4th. Can the absence of the Dingle type of Old Red Carboniferous in Iveragh be accounted for by a limit of deposition coinciding with the Dingle Bay and Killarney Railway fault?

5th. Can the fossiliferous Silurian pebbles of the Dingle-Parkmore conglomerate be contemporaneous with the conglomerate in which they are enclosed as derivative masses?

1. The first and last of these questions are affirmatively supported by Professor Hull, and have doubtless received extensive reconsideration by himself, Mr. O'Kelly, and Mr. M'Henry, of the Irish Survey. I should, therefore, apologise to my friends of that Survey for offering a few observations upon the points referred to, in an imperfect form; partly the result of isolation from means of reference, partly that of the difficulty one finds in recalling with accuracy field observations in this district, made, some of them, nearly a quarter of a century ago.

From the time of my earliest acquaintance with this region it was understood that the softer and coarser type of the Old Red Sandstone (Lower Carboniferous), such as that of Brandon Head and the Three Sisters, was not present in the Iveragh promontory or southwards, but the next higher group, the Yellow Sandstone, was recognised, and a certain upper band of brighter red colour than usual among the Glengariff grit series, was sometimes thought to be on the horizon of the so-called Old Red Sandstone of the Dingle country. The Dingle-Glengariff series was even in those days regarded as the same in both promontories.

Further, if memory does not fail me, there was reason to believe that a perfect transition existed from the redder beds just mentioned, through the Yellow Sandstone into the Carboniferous Slate or Lower Limestone Shale.

The uniform character of the contact between the Lower Carboniferous and the older series over the whole region, shows that both must have been laid down with almost absolute parallelism, and if there is a total discordance this must be an instance of its occurrence, without any degree of disturbance of the older beds or any evidence that the newer were formed derivatively from these.

The apparent obliquity of the contact figured by Professor Hull

(though admitted to be exaggerated in his figure), is in its seeming discordance greatly exceeded by that of consecutive deposition planes shown by Du Noyer to be merely a case of oblique lamination on a huge scale within the beds, near Ventry Harbour on the south side of the Dingle Peninsula.

If such obliquity of contact existed as a rule, between the Dingle-Glengariff series of Iveragh and the Carboniferous beds, it would be presumably as plainly traceable along the surface as in depth, in some parts of this disturbed region; for the axes of the folds are not always parallel to the horizon, nor are these folds always equally compressed. Assuming the floor which received the newer deposits to have been approximately flat, a bed oblique to that surface, making therewith so small an angle as 5°, would, at ten miles distance, as the angle opened, be separated from its basement by nearly a mile in thickness of rocks, almost certainly sufficient to have afforded some stratigraphic difference of aspect, that would force the discordance upon the attention of an observer of the various sections exposed in the country.

But if two sets of beds are in such exactly parallel relation over wide areas as to exhibit the same junction features and with any appearance of transition, how, in the absence of such crucial tests as definitely recognizable layers occurring in the sections, is discordance to be proved, and if necessarily present might it not as well be situated in any part of the Dingle-Glengariff series as at the top.

Unless the supply of rock-forming sediments had been everywhere equally maintained, and equally distributed under immutable conditions, must not all sedimentary beds, groups, and formations thin out or overlap, in the manner shown by Professor Hull's diagrams, even without the existence of a break equal to discordance in the succession?

2. The total area of the country now referred to would be included within a square of sixty or seventy miles on the side. The distance from Dingle to Iveragh across Dingle Bay is about ten miles. The Lower Carboniferous rocks southwards have been denuded so as to remain visible only at a distance of some sixteen miles further to the south, so that they are now thirty-six miles from the Dingle country. But if all the folds of Iveragh and those beneath Dingle Bay were reduced again to approximate

horizontality, the distance would doubtless be greater by several miles. Is it not within the limits of possibility that this distance may have been sufficient for the Old Red beds of the Dingle type—a shore deposit—to have died out towards Kenmare estuary, or changed in their composition so as to be no longer recognizable as lithologically the same.

It seems to me there are many cases in which rocks change their character entirely on the same horizon, in a distance of thirty to forty miles, but the point would of course only be urged as possibly collateral negative evidence in the absence of positive testimony to the contrary.

Is it not also possible, as Professor Mellville used to argue, that within the latter part of the Dingle-Glengariff period, at one locality (Dingle), disturbance, denudation, and discordant deposition, ranging up into the Lower Carboniferous (Old Red) period had taken place, while thirty-six or forty miles away (or more) this disturbance was non-existent, and continuous deposition from the lower to the upper stage was in progress? This point must affect the question until further positive evidence of the discordance in Iveragh is adduced.

3. Supposing this discordance incapable of demonstration, even then it does not seem to me, if complete conformity between the Silurian and the Dingle beds is proved by alternation, there need be any difficulty in adopting Professor Hull's view, that the Dingle-Glengariff beds are more connected with the Silurian than with the Old Red Sandstone horizon of the Carboniferous period. In adopting this view the Carboniferous aspect of the Glengariff beds' plants should be allowed to partake of the uncertainty which seems to cling to deductions based on palæobotany alone. But if there be any ordinary appearances of transition between the Carboniferous slates and Yellow Sandstone and the Dingle-Glengariff series, then the plants of the latter would have a local value in establishing the continuously successional character of these two great series, as opposed to the view, that an unrepresented interval of time prevented their junction beds from being either closely homotaxeous or more generally contemporaneous, in different parts of the south-west of Ireland. The great difficulty would then appear to be how much time might be sufficient to produce within the same area appearances of conformity in

one direction and utter discordance in another. If a long enough period were allowed there seems to be no impossibility in the case, and that there must have been both sea and land somewhere in the neighbourhood, however near or remote, even in the period of the Dingle and Glengariff beds, may be inferred from the existence of land or marsh plants in these presumably marine strata.*

4. I do not recollect to have seen any consideration of the point, whether the apparent anomalies between the Dingle and Iveragh sections could not be accounted for by a limit of deposition or lateral interruption to the extension of the Old Red (Carboniferous) type of deposits. That remarkable feature, the Dingle Bay and Killarney Railway fault, for some part, at least, appears to intervene between the apparently successional and discordant series.

Having regard to this whole south-western area, continuous sequence would appear to be the rule, the discordant deposits the exception. If the northern part of Iveragh and the country eastward had been so gently raised as to maintain the general horizontality of its beds, along an east and westerly line of weakness, an unusually straight shore line might have been produced, against which to the north the whole Carboniferous series of the country might have been accumulating, while representative deposits southwards were being formed in direct succession to the Glengariff beds, or with slight unconformity, or none distinguishable by difference of inclination. Mr. Medlicott has shown, with regard to a part of the Himalayas, that such a limit of deposition, when the rocks on both sides have suffered compression and disturbance, closely simulates a line of fault, and indeed passes along its extension into a genuine line of dislocation, the position being, perhaps, specially favourable to the occurrence of fracture.

Subsequent depression, elevation, and denudation might have left the present state of things in Kerry as their result.

The consideration of this point is only suggested as one among others which may be worth investigating, in studying the pecu-

* Such land need not, however, have been very near, for I have found cast upon the beach at Derrynane bamboos and such tropical flotsam, which, even if derived from some passing ship, must have travelled far in the sea water, to become so highly saturated with its salt as was the case.

liar features of the country. It is, perhaps, as likely to account for these as perfectly parallel, though total, discordance in Iveragh; in favour of which, however, there still remains the ample evidence (eliminating of course all possibility of transition) collected by Mr. M'Henry, and asked for by Mr. Jukes-Browne. This when forthcoming will no doubt have an important bearing on the question, and will be looked for with interest.

5. With regard to the fossiliferous Silurian pebbles in the Parkmore conglomerate, I remember how Du Noyer on finding them contended that the conglomerate must be newer than the newest of the enclosed Silurian fragments, because the fossils occurred in the pebbles and not in the matrix.

The very existence of this conglomerate appears to prove incontestably the co-existence of denudation, which is the only absolute test of discordance. It shows that a varied series of beds, including metamorphic rocks, and others with Caradoc-Bala and Upper Silurian fossils, were undergoing destruction while it was being formed, and it points to the probability that some part of the Dingle beds is not so completely conformable to the Silurian below as has been supposed. That this older unconformity should have escaped detection cannot be considered strange, if it is contended that the discordance between the Carboniferous rocks of Sneem and the Glengariff beds has for years eluded observation, indeed, it would appear that the evidence in favour of discordance below the horizon of the Parkmore conglomerate, is stronger than that for the unconformity at the base of the Carboniferous beds of Kenmare river and estuary.

The discordance connected with the Parkmore conglomerate does not invalidate the supposition that the bed itself may belong to some part of the Upper Silurian series, if the institution of a newer group intermediate between Silurian and Lower Carboniferous should be undesirable. The unconformity might of course have been very local, and might occur anywhere between the highest intercalated bed with Silurian fossils and the conglomerate itself. Regarding this break as possible in some part of the Dingle-Glengariff series, though unrecognizable among its parallel layers, it follows that some conglomerate bed in the upper part of the Dingle-Glengariff series of Iveragh, may also mark an unconformity equally obscure, or that this might occur

even in the absence of such a bed in that region. Hence when ill-defined or invisible unconformities are possible in great series, marked by steady succession, amounting to a monotony of similar alternations, we must hold ourselves ready for surprise, and not count too confidently upon either general or detailed appearances, unless they are those of actual or gradual transition, which could not have occurred otherwise than tranquilly, or those of absolute unconformity, accompanied by discontinuous succession and palpable traces of co-existent denudation, which could not have happened without disturbance. After comparing conclusions past and present, I am unable to see that unconformity in any degree resembling the latter, has been established to exist in the Iveragh country. Unrepresented time may have passed between the deposition of any two beds of rock, an indefinite assertion impossible to fix more than theoretically to any horizon amongst parallel or transitional beds, in most cases. This reduces the position in favour of which it is employed from the status of fact to that of conjecture, the probability of which must be decided on its merits.

As the whole of this interesting subject still engages the attention of very competent observers, we may hopefully look forward to its mysteries being solved, and the geological relations of the rocks in the south of Ireland to each other, and to those of south-western England being fully comprehended at last.

II.—ON A TRAVERTINE FROM BALLISODARE, NEAR SLIGO, CONTAINING A CONSIDERABLE AMOUNT OF STRONTIUM, BY EDWARD T. HARDMAN, F.C.S.

[Read, May 21st, 1880.]

ALONG the shores of the minor bays which indent the coast near Sligo, there is often a considerable deposit of travertine, owing to the water which trickles over the limestone cliffs, dissolving a portion of the carbonate of lime, and again depositing it in a porous form on the slope. Travertine is thus found in abundance at Drumcliff Bay, to the north, and at Ballisodare Bay, to the south; and that at the latter place is interesting from the fact that it contains a very appreciable amount of the rare metal, strontium—probably the only instance in which it is known to occur in a recent calcareous deposit.

The manner in which I noticed this is sufficiently curious to be mentioned. A silver-lead, and zinc mine is at present being worked close by. A mining captain, who was brought from England to examine this, saw the travertine deposit, declared it to be zinc ore, equal to anything he had seen in Spain, and took some specimens for analysis to England. The owner asked my opinion about it, and was incredulous when I pronounced it to be common travertine. However, eventually it was proved to the satisfaction of himself and his practical friend that it was nothing else.

As I had been making some researches on the presence of zinc in limestone rocks, I obtained some specimens for analysis, deeming it likely that from its proximity to the zinciferous limestone the deposit might contain a small amount of the metal. It proved, however, to contain not the slightest trace; but in the course of the examination the presence of strontium was clearly marked.

It is easy to render this visible. Chloride of strontium is soluble in alcohol, and on ignition gives out the well known crimson colour.

Taking some of the travertine, therefore, and placing it in a vessel with hydrochloric acid and alcohol, and then setting fire to the mixture, the presence of the strontium is at once apparent.

The composition of the travertine is as follows :--

Carbonate of Lime,	91·05
Carbonate of Magnesium,	4·50
Carbonate of Strontium,	2·15—3·5
Ferric Oxide and Alumina,	1·80
Insoluble residue,	0·50
	100·00

III.—ON THE MODE OF OCCURRENCE AND DISTRIBUTION OF DIAMONDS IN INDIA, BY V. BALL. M.A., F.G.S., OF THE GEOLOGICAL SURVEY OF INDIA, HON. SECRETARY, ROYAL GEOLOGICAL SOCIETY OF IRELAND.

[Read 21st June, 1880.]

To say that India has for many years been famous for her diamonds would be to enunciate a truism with which everyone is familiar. It is not an easy matter however, to determine for how long this has been the case, still less so to fix with approximate accuracy any period of the world's history as being that when the precious gem first came to be esteemed in the East. At least 3,400 years have elapsed since the first account of it in the Mahabaratta (B.C. 1500) was written—and it may have been known long previous to that. By some it is thought that the Koh-i-noor belonged to King Vikramaditya (B.C. 56), a personage who seems to have been almost ubiquitous, if a tithe of all that is said of him could be believed.

I show below, when describing the diamond localities of Sambalpur that Ptolemy possessed a remarkable amount of information regarding them. Tavernier was of opinion that they were the oldest workings in India.

In this paper I have attempted to give references to the most important authorities on the subject of Indian diamonds,and diamond workings both ancient and modern, but my knowledge of the ancient literature of India is too limited to enable me to give a *résumé* of what may be recorded on the subject in native writings. The late Professor Blochmann, had, I know, culled from many sources notices in Arabic, Persian, and Urdu, on the subject of the mineral productions of India, but these have unfortunately, never been published.

According to Captain Burton the Indian diamond was first made famous in Europe, by the French jeweller, Jean Baptiste Tavernier (born 1605, died 1689), who made six journeys to India in order to purchase precious stones. Previously to the year 1728, the production of diamonds was practically limited to India and Borneo, but in that year the first diggings were opened in Brazil.

Tavernier did not visit Borneo, he tells us, in consequence of having been informed that the queen of that island would not permit of the removal of any gems out of her dominions. But the courageous old traveller seems to have been ready to go anywhere in the pursuit of his trade, undeterred by risks and dangers. He seems to have fared well in India, and often alludes to the courtesy and even the loving kindness of the natives.

I had intended to add to this paper an account of all the famous diamonds which have been found in India;* but at the very outset of my investigations, I have met with so many contradictory and conflicting statements, that I find it will require more time than is available to me at present to hunt up authorities and attempt a reconciliation.

As an example I may state that according to some authorities the Pitt or Regent diamond is said to have come from Borneo, by others, from the mines at Purtial. Similarly the true history of the Koh-i-noor is enveloped in much obscurity.

DISTRIBUTION OF DIAMONDS IN INDIA.

There are in India three extensive tracts, widely separated from one another, in which the diamond has been sought for from the earliest periods of recorded history. Besides these principal tracts, there are others where, although the fact of occurrence of diamonds has been recorded, our knowledge as to the circumstances connected therewith, is less perfect. But with regard to the three principal tracts, it may now be fairly claimed that our knowledge of the geology of India enables us to fix the limits with approximate accuracy, within which the diamond-bearing strata occur, and outside of which it would be useless to look for them. Moreover we may venture perhaps to extend within those limits very considerably the areas in which it may reasonably be anticipated that the gem may be sought for successfully.

The most southern of these tracts is one which has long borne a familiar name, which however must be characterized as being to a certain extent a misnomer. It falls to the lot of those who live in these modern days of accurate research to be called upon to give

* The works on Diamonds and Precious stones by MM. Dieulafait and Harry Emanuel may be referred to for information on these points.

up some of their earliest and most cherished beliefs, and it will be unacceptable to some perhaps to hear that Golconda itself never produced diamonds, and that it was in fact merely the mart where diamonds were bought and sold.

The name originally applied to the capital now represented by a deserted fort in the neighbourhood of Hyderabad was extended to the surrounding district, and seems to have been used for the whole kingdom,* which included many of the diamond localities, and in this way the popular belief on the subject arose; but Golconda fort, it should be remembered, is many miles distant from the nearest of these.

At the present day there is a totally distinct tract of hilly country lying to the north of the Godaveri river, which also bears the name Golconda; whether it at any time formed a portion of the ancient kingdom I cannot say, but it is not, I believe, at present included in the territories of the Nizam of Hyderabad.

The districts included in this southern tract in the Madras Presidency in which there are or have been diamond mines are the following—Kadapah, Karnul, Ellore, and the Karnatic.

Proceeding northwards, the next locality at which there were mines was at Badrachellum on the Godaveri.

The second great tract occupies a considerable area between the Mahanadi and Godaveri rivers. Although diamonds are known but from two neighbourhoods within it, still from our present knowledge of their geology, to which I shall presently allude, it is not improbable that the diamond-bearing strata may have a wide range. The two neighbourhoods referred to are Sambalpur with the bed of the Mahanadi for many miles above it, and Weiragurh or Weiragud eighty miles to the south-east of Nagpur.

Again, as an outlier to this second tract, there are two or three localities within the province of Chutia Nagpur, where diamonds are reported to have been found.

The third great tract is situated in Bandelkhand, near the capital of which, Panna, some of the principal mines are situated; but there are others scattered about in various parts of that province or kingdom.

* "Golconda is the most famous of the six independent Moslem kingdoms which in A.D. 1399 rose on the extinction of the Toghlak (Delhi) dynasty, and it survived till 1688, when Aurungzebe brought all India under one sceptre."—*Captain Burton.*

Some authorities make allusion to a discovery of diamonds in the bed of the Ganges, but I have failed to trace this statement to its source, and I am not in possession of any particulars.

Lastly, about ten years ago, some small diamonds, stated to have been found in a hill stream near Simla, were forwarded by Sir E. C. Bayley to the Geological Museum at Calcutta.

GEOLOGY.

Although in the following pages I shall for each locality give a sketch of the mode of occurrence of the diamonds, it will be well, perhaps, by way of introduction, to give a general account of the formations which include the diamond-bearing beds, and likewise attempt to correlate those of the several localities respectively.

Up to the year 1855 Indian geology was in a condition of extreme confusion, for although much excellent work had been done, chiefly by amateurs, still it was, from the nature of the case, of a scattered and disjointed character, and the attempts at correlation of deposits situated at wide intervals had led to very erroneous conclusions, none of which were further from the truth, as now known, than those having reference to the diamond-bearing deposits.

In the year 1857 a collection of geological papers on Western India, &c., with a summary of the geology of India generally, were printed by the Government, under the editorship of Dr. Henry J. Carter. Valuable as this publication was, its day is now gone by, and it is, therefore, to be regretted that it should still continue to be quoted, not only by discursive writers on India, but even in standard works on general geology.

The publications of the Geological Survey of India, as now constituted, which commenced to appear more than twenty years ago, have from time to time for different areas successively replaced the confusion and incorrect correlation by an orderly arrangement based upon solid evidence. Erroneous conjectures and unsound hypotheses have been overturned by work of that kind, which, especially in a country like India, can only be accomplished by professionals, whose whole time can be devoted to the subject, and whose operations are systematized under the leadership of one central authority.

The issue of the "Manual of the Geology of India" last year places the work of the Survey and our present knowledge of Indian geology in a more accessible and condensed form than it possessed when scattered through the now voluminous publications of the Survey. It is to be hoped that writers of geological text-books will in the future refer to it for their facts, rather than to the old sources of information, and that we shall never again see the "diamond sandstone," so called, classed as an Indian representative of the European Oolite.

Among the authorities quoted by Dr. Carter in reference to the diamond-bearing strata, the following are the principal:—Heyne, Jacquemont, Franklin, Voysey, and Newbold.

Some of these, especially Heyne, maintained that the diamond occurred only in a superficial recent conglomerate, formed of a great variety of fragments of the surrounding rocks, and resting indiscriminately on old rocks of different ages. Others recognised that in some cases the matrix of the gem was a conglomerate, which was a member of the clay slate formation, so called. This "clay slate formation," which included sandstones and limestones, and all their varieties now embraced in the Vindhyan formation, were considered to be the altered representatives of the Oolite, this being the age assigned to the coal-measures and associated plant and reptilian fossil-bearing sandstones. The latter were in fact held to constitute the unaltered portion of the rocks of the same period. The work of the Survey has demonstrated that this clay slate, or diamond sandstone, or Vindhyan formation is separated by a wide break in time from the fossil-bearing rocks, being itself, so far as is known, absolutely azoic, and occupying a position in the geological sequence, which may range from Lower Silurian to Carboniferous.

Further reference to the fossiliferous rocks will therefore be unnecessary in this paper.*

Dr. Carter arrived at the conclusion that the diamond-bearing conglomerates described by various authorities, occurred, at least, in the neighbourhood of, if they did not constitute members of, the Oolite formation. If for Oolite the term Vindhyan be

* They will be found described in my paper "On the Coal Fields and Coal Production of India."

substituted, the conclusion is probably in the main correct, and borne out by the most recent researches. But these researches have demonstrated that the principal diamond-bearing strata of the northern and southern areas respectively occupy distinct horizons, in those cases where the beds are not merely recent or sub-recent accumulations of debris.

It is due to Captain Newbold to say that he disagreed with the conclusions of many of the previous authorities, and he appears to have been inclined to regard the 'sandstones' as being of Devonian age—a supposition probably not very far from the truth.

The Vindhyan rocks of Northern India are separated into two formations or sets of groups, distinguished as Upper and Lower.

In Southern India, and possibly also in the Central Mahanadi-Godaveri tract, it is considered that the lower set of groups is alone represented, and the two have been correlated, as follows:—

On the southern rocks the local title of Karnul formation has been conferred.

	Northern India. *Vindhyan Formation.*		Madras. *Karnul Formation.*
Upper.	Bhanrer Group.		
	Rewah „ (*diamonds*).		
	Kaimur „		
Lower.	Tirhowan Limestone	=	Khundair Shales and Limestones.
	Palkoa Shales		
	Dalchipur Sandstones	=	Panoum Quartzites.
	Semri Shales and Limestone	=	Jamalmadgu Shales and Limestone.
	Semri Sandstone	=	Banaganpili Sandstones (*diamonds*).

At Panna, in Bandelkhand, diamonds are only known certainly to occur *in situ* in a conglomerate which is referred to the Rewah group. There are, however, as elsewhere, numerous workings in alluvial or superficial deposits; but the greatest amount of labour is spent in mining in this the bottom bed of the group, which, though it has a wide extension, has only as yet been ascertained to be diamond-bearing in the neighbourhood of Panna. Although diamonds have not been obtained directly from any lower group, it would appear that this conglomerate is largely made up of pebbles derived from the lowest or Semri sandstone group, and since it is stated* that diamonds are sometimes found in these pebbles

* Mr. Medlicott, from whom I quote, states that this needs confirmation. The statement was made to him by a native miner.—*Manual*, p. 92.

when broken up, it would seem that the latter must include an earlier if not the original matrix of the gem. This point is of great interest, since it brings us to a horizon, the base of the formation, which is strictly comparable with that of the Banaganpili group, which includes the lowest known matrix in Southern India. The order of succession of the rocks in the Mahanadi-Godaveri tract has not yet been ascertained; but from the fact of the only known localities where the diamond occurs being situated on the margin of the area, it may with a considerable degree of probability be assumed (notwithstanding possibly faulted boundaries) that the matrix is in a bed close to the base of the formation.

With regard to the minor areas, the Badrachelum diamonds may perhaps have been derived from some of the Karnul or Vindhyan rocks in the neighbourhood of the Godaveri.

The geology of the Chutia Nagpur localities is not yet known, but it is probable that in their vicinity an outlier of the Mahanadi-Godaveri rocks may exist.

The Simla diamonds, if the find be authentic, are of considerable interest, for although, as has been shown, diamonds *per se* do not afford evidence sufficient for exact correlation, still when it is remembered that according to some authorities the older Palæozoic rocks of the Himalayas present many points of resemblance with those of the Peninsula, the possibility of the matrix containing these diamonds being on a horizon comparable to that in the Banaganpili group of the Karnul (L. Silurian?) formation cannot fail to suggest itself.

As particulars regarding the exact *locale* whence the diamonds were brought is not available, it would be useless to enter further here into any account of the geology of the neighbourhood of Simla.

Mr. Griesbach, of the Geological Survey of India, has recently published some interesting remarks upon the correlation of the Vindhyan rocks of India, with certain series occurring in South Africa, to one of which the sandstones of the Table Mountain belong. The possibility of the Cape diamonds therefore belonging to a period or horizon directly comparable to that which includes the Indian diamonds does not fail to suggest itself as a subject

worthy of future investigation. A comparison of the geology of Borneo with that of India may also prove productive of interesting results in this respect.

But the incorrect conclusions of the earlier writers, drawn from imperfect data, which I have noticed above, as to the age of the diamond-bearing strata in India, afford a sufficient warning of the danger of premature attempts at correlation.

Origin of the Diamond.

The examination of the diamond-bearing strata of India has not resulted, so far as I know, in throwing any definite light on the yet unsettled question as to the conditions under which the crystallization of carbon took place, thus forming the precious gem which has occupied so important a position in history. Light regarding the subject seems to be destined to reach us indeed from another quarter, and it is to the synthetical operations of the laboratory, which it is needless to point out have made such great advances in this direction of late years, that we must look for the true explanation.

But the absence of any clear evidence on the subject may be due to the fact that it is still a matter of doubt whether in any single recorded case in India a diamond has been found in its original matrix. The lowest diamond-bearing stratum, at the base of the Karnul series, is itself a detrital conglomerate, and it is not unreasonable to suppose that the diamonds may, like the other ingredients, have been derived from some older metamorphosed rocks.

Mr. King* discusses some apparent cases of mines in the Kadapah series of rocks which underlie the Karnuls, but he says there is " still a doubt as to whether true rock-workings in these beds were ever successful."

Elsewhere, *l.c.*, p. 101, however, he states of the diamonds shown to him at Banaganpilly that—

"Nearly all the specimens were more or less perfect modifications of the octahedron, with curved facets, one of them had each of its facets crowned with a little pyramid of tables.†

* Memoirs of the Geological Survey of India, Vol. viii., p. 88.

† Strangely enough, Newbold speaks of the diamonds shown to him at the same locality as being " but imperfectly crystallized."—*J. R. A. S.*, Vol. vii.

"They were smooth, tolerably bright and shining, and did not look as if they had been worn; in fact, they seemed to me to have been crystals *in situ* in the rock. In colour they were pale blue, or green and yellow.

Captain Newbold, in discussing this subject, without much difficulty disposes of Captain Franklin's suggestion that the beds containing the diamonds of Panna may have been roasted by the ignition of coal seams, which he believed existed below. He then remarks:—" It is fully proved, I think, from the experiments of Sir David Brewster, that the diamond has once been in a soft state, like amber, opal, or the tabashir. Minute cavities, surrounded by a compressed structure, analogous to those in the Laske diamond, are seen in several specimens of the Indian gem which have been brought me by the diamond merchants." He appears to be disposed to favour the native idea that the diamond is reproduced in the soil. "The old miners stated to me that a term of fifteen or twenty years was requisite for the reproduction of the gem." They were in this belief led to rewash old tailings, and accounted for the fact of the diamonds found in them being so small by saying that they had not had time to grow larger. An unbeliever in this hypothesis would be inclined to suggest that the smallness of the diamonds accounted for their having eluded the searchers in the first washings.

The same idea was favoured by Dr. Heyne, and it may be added that various authorities have expressed a belief that alluvial gold is formed by accretion of particles *in situ*, some even having asserted that they have positive proof of the fact. But I do not know that this proof has ever found expression in a form calculated to carry with it conviction to any impartial expert. In point of fact it is one which cannot really be seriously entertained for a moment, and I merely mention it because it occurs in the early accounts.

KADAPAH, OR CUDDAPAH, DISTRICT.

Within the limits of the Kadapah district the principal localities where diamonds have been worked for are, according to Mr. King, Cunnapurtee and Woblapully, or Obalumpally, near Chennur, on opposite banks of the Pennair and Lamdur rivers, and Pinchetgapadu, west of Chennur.

These mines are generally by authors referred to under the title.

Chennur, or Chinon.

This is a village near Kadapah town, where there are deserted pits, which were sunk in gravels, derived from the disintegration of the Banaganpilly quartzites, and lie below the black cotton soil (or regur). These have recently been reopened by a Mr. Richardson, of Madras, who applied to the Collector of Kadapah for permission to work the mines in 1869, at the favourable rent of 100 rupees per annum. The result is not known, but there are accounts of two diamonds having formerly come out of this field which were eventually sold for 5,000 and 3,000 rupees each.*

Cunnapurtee, or Condapetta.

This locality appears to be identical with the Condapetta of Captain Newbold, whose detailed account is, perhaps, of sufficient interest to be quoted *in extenso*. He says:—†

"At Condapetta the mines are generally of a square form, and from four to twelve feet deep. The stratum cut through is of cotton soil, mixed with small grains of quartz, generally from three to ten feet thick, which rests immediately on a bed of rolled stones of various sizes, from that of a paving stone to a nut, in which the diamonds are found, generally loose, but sometimes adherent. The stones are mingled with mud and gravel. The pebbles most commonly met with are ferruginous, gritty, and schistose sandstones, sandstone conglomerates, embedding rolled pebbles of quartz, chert and jasper; claystone porphyry, with crystals of felspar; blue jasper, veined with oxide of iron; coarse, red jasper, and quartz crystals. Some of these pebbles have evidently been transported from the adjacent hills, but the porphyritic and felspathic pebbles must have travelled a much greater distance. Near the base of the hills the cotton soil is covered with the red gritty earth, arising from the disintegration of the sandstone rock.

"The process of mining consists merely in digging out the rolled pebbles and gravel, and carrying them to small square reservoirs raised on mounds, having their bottom paved with stones, and washing them carefully. At the foot of the mound is a clear space surrounded by heaps of refuse, where the washed gravel is again carefully spread out and examined in presence of the diamond contractors; the diamonds are easily recognised in the moist state by their peculiar lustre. These mines are let out by the Government to native contractors, who gave me the following information on the spot. In 1834, the mines proved profitable, but in the following year the miners lost a considerable sum.

* King, Records Geological Survey, Vol. ii., p. 9; and Memoirs Geological Survey, Vol. viii., p. 106.

† J.R.A.S., Vol. vii., p. 226.

The sum paid to Government by them for the privilege of mining a piece of ground 100 yards long by 50 broad, for four months, is 200 * rupees.

"Dry weather is selected to carry on operations to avoid the inconvenience and expense of draining. In former days all the diamonds produced were carried for sale to Golconda. In those times very large diamonds were found; but subsequent to British ascendency—which according to the superstitious natives is by no means pleasing to the tutelary deities of the mines—few of any value have been found, probably in consequence of their being less looked after. However, lately in 1839, a fine diamond of the Kshatriya or roseate caste was dug from the Obalumpally mine, exceeding a gold pagoda in weight, which was sold for 1,450 rupees."

KARNUL DISTRICT.

Mr. King's list of diamond localities in the Karnul District † is as follows:—

BANAGANPILLY, .	37 miles, S.S.E. of Karnul. Rock workings worked.
MOONIMUDDAGOO,	16 miles, W. of Banaganpilly. Rock workings. Deserted.
RAMULKOTA, .	18 miles, W. by S. of Karnul. Alluvial washings. Worked. Rock workings deserted.
TIMAPOORAM, .	6 miles E.S.E. of Ramulkota. Rock workings. Deserted.
ZEMBE, . BYANPULLY, . GOORAMANCONDA,	24 miles, S.S.E. of Karnul. Rock workings. Deserted. (Captain J. G. Russell *teste*.)
GOODYPAUD, . BANNOOR, . DEVANOOR, .	Nundycotkoor talug. Doubtful localities. (Captain J. G. Russell, *teste*.)
SHAITANCOTAH, .	Right bank of Toongabudra, E.N.E. of Karnul. Deserted.
DEOMURROOH, .	Left bank of Toongabudra. Deserted.
TANDRAPAD, .	" " Alluvial deserted.
BUSSWAPOOR, .	Nullamullays. Rock workings and alluvial washings. Deserted.

BANAGANPILLY.

The diamond mines at this locality have been visited and described by many writers. Heyne, Newbold, Malcolmson, and Voysey, have all left on record accounts of them.

Mr. King's already mentioned report, containing the latest and most authentic account of them, it will be best perhaps to quote from it a few passages verbatim at the same time, stating that Mr. King refers those who are likely to be specially interested to Dr. Heyne, for an account of the mines as they appeared in his day.

* In 1840, the contract rose to about 250 rupees. When a diamond of more than a gold pagoda in weight (=52·56 grains at Madras) is found, it is sold by public auction, and one-third of the proceeds goes to Government, the remainder to the mining contractor.

† Memoirs of the Geological Survey of India, Vol. vii., p. 106

Mr. King writes:—

"The quartzites of the Banaganpilly group form a cap, resting unconformably on the denuded surface of a much older set of shales and traps with some limestone bands . . . The quartzite covering is from 20 to 30 feet in thickness; and it is pierced here and there over the Banaganpilly end of the hill, by shafts of 15 feet or less, from the bottoms of which nearly horizontal galleries are run to get at the seams of diamond gangue. The capping is composed of compact grits and sandstones in thickish beds above, and somewhat thinner bedded towards the bottom.

"Externally the rocks are hard and vitreous. At the level of the galleries there are *beds of coarse pebbly conglomerate, occasionally a breccia* which are sandy and clayey, and with these run seams of more shaley and clayey stuff. There is no trace of the clayey constitution on the outside along the outcrop, nor are there any distinct bands of shales; there are only some sandy shales down at or near the bottom of the series.

". . . In the mines the coolees were picking out a seam of about six or eight inches in thickness, occurring with thicker and harder beds of sandstone, and which they said was the diamond layer; this rock when brought to light turned out to be an easily broken up damp clayey conglomerate and partly breccia, of small rounded fragments and pebbles of black, red, green, and pale coloured shales and cherts, and of quartzite with large and small grains of dirty and pellucid quartz. This was the rock extracted in all the mines then being worked. The gangue is then pounded up, washed, sifted and laid out to dry on prepared floors, after which the residue of clean sand is carefully examined in the hand, by the women and children of the working parties, for the precious gems. I saw no diamonds *in situ*, nor did I see or hear of any diamond being found during my stay at Banaganpilly for four or five days at a time. Diamonds were brought to me which were reported to have been found in the mines; but these were most disappointing in their minuteness, flaws and dirty colours."

I have already quoted Mr. King above as to the crystalline forms of these samples.

He says that the good specimens were valued at only ten rupees by the merchants. But one specimen said to have come from the Bellary District; but which he thought had probably been found on the spot, was valued at 350 rupees.

"Neither the Nawab of Banaganpilly nor his followers, nor the Tehsildar of the place, nor the merchants could, or would, tell me of any better diamonds having been found for many years."

Mr. King tracked the diamond-bearing strata for some miles westward, beyond the region wherein it is worked.

MOONIMUDDAGOO.

In the neighbourhood of Moonimuddagoo sixteen miles west-by-south of Banaganpilly there is a continuation of the diamond-bearing strata, which cover the older Kadapah rocks as with a thin skin. The locality is described both by Mr. King and Captain Newbold. The mines have long been deserted, but according to the last named authority, there was in his time a colony of diamond polishers in the town.

RAMULKOTA.

The position of these mines is variously stated as being from eighteen to twenty-one miles from Karnul, in a southerly direction. They are also described by Mr. King and Captain Newbold.

They are now merely alluvial washings in the debris of the Banaganpilly group, but formerly there were regular mines. Captain Newbold says:—

> "The pits, though not occupying so large a superficies, are deeper and far more extensive than those near Kadapah, the old excavations in the rocks resemble those of Banganapilly and Moonimudgoo. The diamonds that were shown me here, one in the parent rock, the conglomerate, were of an inferior size and but few crystallized in the octohedral form. They had severally white, grey, yellow and greenish tints, but it was told me that those found in the conglomerate rock are generally of a superior description with a fine roseate tinge."

Mining and washing is carried on as at Kadapah. There are 300 natives at work in the wet season, but only 20 when visited by Newbold.

The contractors lease the mines for 750 rupees from the Nawab of Karnul, and sublet to minor speculators.

The hire of a labourer is four pice or about three halfpence, and a meal of rice *per diem.*

The exact identity of the locality described by Tavernier as Raulkonda in the Karnatic, I have not been able to make out a similarity in the sound suggests that it may have been the same as the above, but the description of the geographical positions respectively, do not agree. Possibly it should be identified with the modern Rowpoor to the east of Kadapah.

RAOLKONDA IN THE KARNATIC.

This was the first mine visited and described by Tavernier,* who stated that it was five days journey from Golconda, and eight or nine from Visapour. This place is perhaps identical with Volcondah, in Trichinipoli, lat. 12° 20′.

"The strata containing the diamonds ranged from half an inch to an inch in thickness, and the gangue was hooked out with iron rods. Some of the stones were valued at from two to sixteen thousand crowns. The steel wheel was used for cutting."†

Tavernier gives an account of the polishing of the gems as practised here. His account of the great security of property and system, with reference to the sale of diamonds, together with the courtesy with which he was treated, will be read generally with interest.

Proceeding north-westwards from Karnul the next locality is Gani.

GANI‡ on the Bhima influent of the Krishina, so called by Tavernier, known to the Persians as Coulour, and at present bearing the name Barkalun, according to Captain Burton.

Tavernier's account of the mine at this locality is, as follows:—§

"It is not above a hundred years since this mine was discovered by a countryman, who digging in a piece of ground to sow millet, found therein a pointed stone that weighed above twenty-five carats. He, not knowing what the stone was, but seeing it glisten, carried it to Golconda, where, as it happened well for him, he met with one that traded in diamonds. The merchant informing himself of the place where the stone was found, admired to see a jewel of that bigness, not having seen before one that weighed ten or twelve carats. However, his report made a great noise in the country. Inasmuch that the moneyed men in the town set themselves to work, and causing the ground to be searched they found and still do find bigger stones and in greater quantity than in any other mine, for they found a great number of stones from ten to forty carats, and sometimes bigger, among the rest that large stone that weighed 900 carats, which Mirimgola presented to Aurengzeb.||

* Travels. Book II. Pt. II., Chap. XI. Of diamonds and the mines and rivers where they are found, and first of the author's journey to the mine of Raolconda."

† Quoted from Capt. Burton, Quarterly Journal of Science, N.S., Vol. vi., 1876.

‡ Written Garree by Dieulafait, 'Diamonds and Precious Stones.' London, Blackie, 1874.

§ Travels, Chap. XII.

|| This by some authorities is thought to have been the Koh-i-noor, which is said to have been found in the year 1550.

"After the miners have pitched upon the place where they intend to work they level another place close by, of the same extent, or else a little bigger, which they enclose with a wall about two foot high. In the bottom of that little wall, at the distance of every two foot, they make small holes to let in the water, which they stop up afterwards till they come to drain out the water again. The place being prepared the people that are to work meet all together, men, women, and children, with the workmaster in the company of his friends and relations. Then he brings along with him some little image of the god that they adore."

After worship of this and a feast of rice, Tavernier continues:—

"When the feast is over the men fall to digging, the women and children to carry earth to the place prepared in that manner as I have already described. They dig ten, twelve, and sometimes fourteen feet deep, but when they come to any water they leave off.

All the earth being carried into the place before mentioned, the men, women, and children throw the water which is in the drains upon the earth, letting it soak for two or three days according to the hardness of it, till it comes to be a kind of batter, then they open the holes in the wall to let out the water and throw on more water still, till all the mud be washed away and nothing left but the sand. After that they dry it in the sun, and then they winnow the sand in little winnows as we winnow our corn.

". . . The earth being thus winnowed, they spread it into a kind of rake, as thin as they possibly can; then with a wooden instrument, like a paviour's rammer, about half a foot wide at the bottom, they pound the earth from one end to the other two or three times over. After that they winnow it again then, and spreading it at one end of the van, for fear of losing any of the earth, they look for the diamonds. Formerly they were wont to pound the earth with great flintstones instead of wooden rammers, which made great flaws in the diamonds, and is, therefore, now left off.

"The first time I was at the mine there were about 60,000 persons at work—men, women, and children; the men being employed to dig, the women and children to carry the earth."

ELLORE DISTRICT.

The principal mines in the Ellore district are situated on the banks of the Kistna, or Krishna. They are named Golapilly Malavilly, and Purtial.

GOLAPILLY.

The diamond pits at this locality, according to Mr. King, were sunk in conglomerates and pebble beds of tertiary age* (Rajahmundry Sandstone group). Mr. Blanford† says that the—

* Records of the Geological Survey of India, Vol. x., p. 58.

† Idem, Vol. v., p. 27.

"Diggings appear not to have been in the sandstone itself, but in the very gravelly laterite which rests upon the sandstone, but the surface is so much broken and altered by the pits that it is difficult to say. The workings cover a very considerable area."

At the time of Mr. Blanford's visit (1871) these mines had the appearance of having been long abandoned, being covered with bush jungle.

Dr. Heyne (Tracts) stated that—

"In the Ellore district the diamond stratum is covered by a thick stratum of calcareous trap."

This does not appear to have been confirmed by any subsequent writer, and is apparently a mistake. The thickness of the conglomerate is said to be from two to six feet thick, perhaps more in some places.

MULAILY, OR MALAVILLY, N.E. OF BEZWARRA.

As at Golapilly, the mines here also were in tertiary conglomerates (King). Captain Newbold* describes the bed of gravel in which the pits were sunk as being "composed chiefly of rolled pebbles of quartz sandstone chert, ferruginous jasper, conglomerate sandstone, and *kankur*, lying in a stratum of dark mould about a foot thick." He appears, according to Mr. King, to have been wrong in identifying this deposit, which rests on gneiss, with the true old diamond conglomerate of Banaganpilly, of which it should, therefore, not be regarded as an outlier—though, doubtless, there is some similarity in the component pebbles, &c., which form both rocks.

Dr. Benza believed the conglomerate to be continuous from hence through Ellore and Rajahmundry, to Samulcotah, where also diamonds are said to have been found.

PURTIAL, OR PURTEEALI.

The mines so called are situated near a village of the same name, which is not far from

"Kondapilly, about 150 miles from Hyderabad, on the road to Masulipatam. The property of them was reserved by the late Nizam when he ceded the northern circars to the English Government. They are superficial, not extending ten or twelve feet deep in any part. For some years past the working of them has been discontinued."

* Geological Notes, p. 67, of Carter's Collection of Geological Papers.

Mr. Briggs, the author of the above, who is quoted by Captain Burton,* adds :—

" And there is no tradition of their ever having produced very valuable stones."

Captain Burton remarks upon the statement that it is full of error, as the Pitt or Regent diamond came from Purtial, but Captain Newbold says it came from Borneo, being bought by Mr. Pitt, a merchant, of Bencoolen, in Sumatra.

Regarding the origin of these diamonds from the various localities bordering the Kistua river, near Kondapilly, Captain Newbold expresses his belief that the materials of the beds were brought down from the hills of sandstone and limestone through which the river has recently passed, and Voysey remarks the persistency of the same kind of conglomerate at all the mines.

CENTRAL PROVINCE OR MAHANADI—GODAVERI TRACT.

SAMBALPUR.

In Rennell's " Memoir on a Map of Hindustan,"† the following passage occurs :—

" On the west of Boad and near the Mahanuddy river, Mr. Thomas passed a town of the name of Beiragurh, which I take to be the place noted in the Ayin Acbaree as having a diamond mine in its neighbourhood. There is, indeed, a mine of more modern date in the vicinity of Sambalpur; but this whole quarter must from very early times have been famous for producing diamonds. Ptolemy's *Adamas* river answers perfectly to the Mahanuddy, and the district of *Sabaræ*, on its banks, is said to abound in diamonds Although this geographer's map of India is so exceedingly faulty in the general form of the whole tract, yet several parts of it are descriptive."

With reference to Beiragurh, I can find no place of that name in Sambalpur, and the late Mr. Blochmann, to whom I referred the matter, informed me that the Beiragurh mentioned in the Ain Akbari is there stated to be in the *Subah* Berar, and was, therefore, probably not identical with the place mentioned by Mr. Thomas, according to Col. Rennell.‡ In Ptolemy's map§ the

* Quarterly Journal of Science, N.S., Vol. vi., 1876.

† London, 1792, p. 240.

‡ One of the diamond localities in Panna is called Baraghari.

§ Asiæ x. tab. "Geographiæ libri Octo, Gr. et Lat. Opera P. Bertii Lugduni." Bat 1618. Fol.

Adamas flows into the Gangeticus sinus (Bay of Bengal), midway between Cosamba on the north (Balasore ?) and Cocala. (Sicacole of Arrowsmith's map, the modern Chicacole). The Dosaron and Tyndis rivers probably represent the Godaveri and Kistna, so that it is very likely that the Adamas may safely be identified with the Mahanadi. Ptolemy represents the Adamas as flowing through the district of Sabaræ, across which runs the following description :—" *Apud quos adamas est in copia,*" which is otherwise given in an earlier edition of the map.* " *Sabaræ in his habundat Adamas.*" [In Sabaræ the diamond occurs in abundance.] The upper portion of the river passes through a district named Cocconage, which would include Chutia Nagpur.

The first visit to these mines of which I have been able to find a record was made by the already-mentioned French jeweller Tavernier,† who appears to have gone there somewhere about 1665. He says :—

"I come to the third mine, which is the most ancient of all, in the kingdom of Bengala. You may give it the name of Soumelpour, which is the name of the town next to the place where diamonds are found, or rather Gouel, which is the name of the river in the sand whereof they seek for the stones. The territories through which this river runs belong to a Raja who was anciently tributary to the Great Mogul, but revolted in the time of Shah Jehan and Gehan Guir, his father. So soon as Sha Jehan came to the empire he sent to demand his tribute of this Raja, as well for the time past as to come, who, finding that his revenues were not sufficient to pay him, quitted his country, and retired into the mountains with his subjects. Upon his refusal Sha Jehan, believing he would stand it out, sent a great army against him, persuading himself that he should find great store of diamonds in his country. But he found neither diamonds nor people, nor victuals—the Raja having burnt all the corn which his people could not carry away, so that the greatest part of Sha Jehan's army perished for hunger. At length the Raja returned into his country, upon condition to pay the Mogul some slight tribute."

Then follows an account of the route travelled over by Tavernier from Agra, *via* Allahabad and Rhotas to Sambalpur. He continues :—

"Soumelpour is a great town, the houses whereof are built of earth, and covered only with branches of coco ‡ trees. All these 30 leagues

* Tab. x. "Cosmographiæ," libri viii. Lat. Justi de Albano, Ulmae. 1486. Fol.

† Travels. London, 1678. Book ii., chap. xiii., p. 139.

‡ Probably the leaves of the Tal palm. The Cocoa-nut does not occur at present in Sambalpur. Elsewhere, however, it has been found at as great a distance from the sea.

[*i.e.* from Rhotas to Sambalpur], you travel through woods, which is a very dangerous passage, as being very much pestered with robbers.

"The Raja lives half a league from the town in tents, set upon a fair rising ground, at the foot whereof runs the Gouel, descending from the southern mountains, and falling into the Ganges.

"In this river they find the diamonds. For after the great rains are over which is usually in December, they stay all January till the river be clear, by reason that by that time in some places it is not above two feet deep, and in several places the sand lies above the water.

"About the end of January or the beginning of February, there flock together out of the great town, and some others adjoining about eight thousand persons, men, women, and children, that are able to work. They that are skilful know by the sand whether there be any diamonds or no, when they find among the sand little stones like to those we call 'thunder stones.' They begin to make search in the river from the town of Soumelpour to the very mountains from whence the river falls for fifty leagues together.

"Where they believe there are diamonds, they encompass the place with stakes, faggots and earth as when they go about to make the arch of a bridge, to drain all the water out of that place. Then they dig out all the sand for two feet deep, which is all carried and spread upon a great place for that purpose prepared upon the side of the river, encompassed with a little wall about a foot and a half high.

"When they have filled this place with as much sand as they think convenient, they throw water upon it, wash it, and sift it, doing in other things as they do at the mines, which I have above described.

"From this river come all those fair points which are called natural points; but a great stone is seldom found here. The reason why none of these stones have been seen in Europe, is because of the wars that have hindered the people from working."

The next visit of which there is any published account is described in the narrative of a journey which was undertaken by Mr. Motte in the year 1766.* The object of this journey was to initiate a regular trade in diamonds with Sambalpur, Lord Clive being desirous of employing them as convenient means of remitting money to England. His attention had been drawn to Sambalpur by the fact that the Raja had, a few months previously, sent a messenger with a rough diamond, weighing 16½ carats, as a sample, together with an invitation to the Governor to depute a trustworthy person to purchase diamonds regularly. The Governor proposed to Mr. Motte to make the speculation a joint concern, "In which," writes the latter, "I was to hold a third; he the other two; all the expenses to be borne by the concern.

* "Asiatic Annual Register," London, 1799

The proposal dazzled me, and I caught at it, without reflecting on the difficulties of the march, or on the barbarity of the country, &c."

In spite of his life being several times in danger from attacks by the natives, the loss of some of his followers by fever, and a varied chapter of other disasters, Mr. Motte was enabled to collect a considerable amount of interesting information about the country. Owing to the disturbed state of Sambalpur town, however, he was only able to purchase a few diamonds. After much prolonged negotiation, he was permitted to visit the junction of the Rivers Hebe (Ebe) and Mahanadi, where the diamonds were said to be found. A servant of the Raja's who was in charge there, informed him that "it was his business to search in the River Hebe, after the rains, for red earth, washed down from the mountains, in which earth diamonds were always found. I asked him if it would not be better to go to the mountains and dig for that earth. He answered that it had been done, until the Maharattas exacted a tribute from the country; and to do so now would only increase that tribute. He showed me several heaps of the red earth—some pieces, of the size of small pebbles, and so on, till it resembles coarse brick-dust—which had been washed and the diamonds taken out."*

Mr. Voysey on his last journey, from Nagpur to Calcutta in 1824, visited the diamond washings of Sambalpur.

He mentioned that the gems were

"Sought for in the sand and gravel of the river—the latter consisting of pebbles of clay slate, flinty slate, jasper, and jaspery iron stone of all sizes, from an inch to a foot in diameter." †

The next mention of Sambalpur diamonds is to be found in Lieutenant Kittoe's account‡ of his journey, in the year 1838, through the forests of Orissa. He speaks of the people as being too apathetic and indolent to search for diamonds. His remarks on the localities where they occur seem to be derived from Mr. Motte's account, to which, indeed, he refers.

* This description suggests laterite as the matrix from which the diamonds were proximately derived. Messrs. Hislop and Hunter (*vide infra*) describe the diamonds of Weiragurh, as occurring in laterite gravel. In this connexion it may be noted that one of the principal sources of Cape diamonds is said to be a superficial ferruginous conglomerate.

† *Vide* Carter's Summary of the Geology of India, p. 724.

‡ "Journal Asiatic Society, Bengal," Vol. viii., 1839. p. 375.

Although published in the same number of the Asiatic Society's Journal* we find a paper dated two years later, or 1840, which was written by Major Ouseley, on the "Process of Washing for Gold-dust and Diamonds at Heera Khoond." In this we meet the following statement:—

The Heera Khoond is that part of the river which runs south of the islands. The diamonds and gold-dust are said to be washed down the Ebe River, about four miles above the Heera Khoond; but as both are procurable as far as Sonpur, I am inclined to think there may be veins of gold along the Mahanadi."

The occurrence of diamonds in the river so far below Sambalpur as Sonpur, must have been very exceptional. No mention is made by Major Ouseley of the system of throwing an embankment across one of the channels, which is described below; but from my inquiries I gathered that that method of washing was in practice for many years before the period of Major Ouseley's visit. He describes the operations of individual washers—not the combined efforts of the large number, which made that washing successful. The diamonds found became the property of the Raja, while the gold was the perquisite of the washers, who sold it for from twelve to fifteen rupees a *tola*.

Captain Newbold says,† that "diamonds of considerable value are also found in the bed and alluvium of the Mahanadi River, especially at Sambalpur, and about the mouths of the Hebe, Khelu, and Mand streams, but their beds have not hitherto, I believe, been traced." Captain Burton mentions‡ that according to some authority not named, the Majnodi, a tributary of the Mahanadi, contained diamonds.

In the *Central Provinces Gazetteer* it is stated that:—

"During the period of native rule some fifteen or twenty villages were granted rent free to a class called *Jhiras*, in consideration of their undertaking the search for diamonds. When the country lapsed in 1850, these villages were resumed."

So far as can be gathered from the various sources of information, large and valuable diamonds have been occasionally met

* Journal Asiatic Society, Bengal, Vol. viii., 1839, p. 1057.

† Jour. Roy. Asiatic Society, Vol. vii.

‡ Quarterly Journal of Science, N.S., Vol. vi., 1876, p. 351.

with; but the evidence on this point is somewhat conflicting. I do not think, however, that what we know is altogether consistent with the statement in the *Gazetteer*, that "the best stones ever found here were thin and flat, with flaws in them."

Local tradition speaks of one large diamond, which was found during the Maharatta occupation. Its size made its discovery too notorious; otherwise it would in all probability, like many other smaller ones, found at that time, never have reached the hands of the Maharatta agent. It is said to have weighed two tolas and two mashas (at ten mashas to the tola)* which would be about 316·2 grains troy, or expressed in carats 99·3. It would be impossible, of course; to make any estimate of the value of a rough stone of this size, regarding the purity, colour, &c., of which nothing is known.† Another diamond, in the possession of Narain Singh, is said to have weighed about a *tola*, the equivalent of which, calculated as above, would be 45·35 carats. Already one of 16·5 carats has been mentioned as having been sent to Calcutta in 1766. One large, but slightly flawed diamond, which I saw in the possession of a native in Sambalpur, was valued in Calcutta, after cutting, at Rs. 2,500. Mr. Emanuel, in his work on "Diamonds and Precious Stones," gives some particulars regarding the diamonds of Sambalpur, but the limited information at his disposal does not appear to have been very accurate. He records one diamond of 84 grains having been found within the period of British rule, but does not mention his authority. There are said to be a good many diamonds still in the hands of the wealthier natives in Sambalpur. Of course, large diamonds such as those above mentioned, are of exceptional occurrence; those ordinarily found are said to have weighed, however, two to four rutties, equal on an average, say, to the thirtieth part of a tola, or 4·7 grains = 1·48 carats. In the Geological Museum at Calcutta there is at present a diamond which was sent to the Asiatic Society of Bengal, from Sambalpur, by Major Ouseley. It weighs only ·855 grains = ·26 carats.

* (One masha=14·87 grains troy): properly speaking there are 12 mashas in a standard tola.

† Tavernier's method of ascertaining the value of any diamond was to square the number of carats, and then multiply the result by the value of a one-carat stone of equal purity.

As is usual, I believe, in all parts of India, the diamonds were classed, as follows:—

I.—*Brahman.*—White, pure water. II.—*Kshatrya.*—Rose or reddish. III.—*Vasiya.*—Smoky. IV.—*Sudra.*—Dark and impure.

With regard to the origin of the Sambalpur diamonds, the geological structure of the country leaves but little room for doubt as to the source from whence they are derived. Coincident with their occurrence is that of a group of rocks, which has been shown to be referable to the Vindhyan series, certain members of which series are found in the vicinity of all the known diamond-yielding localities in India, and in the cases of actual rock-workings, are found to include the matrix of the gems.

In several of the previous accounts, the belief is either stated or implied that the diamonds are brought into the Mahanadi by its large tributary the Ebe. It would not, of course, help the point I am endeavouring to establish as to their origin, to say that the Ebe, at least within our area, except indirectly,* is not fed by waters which pass over Vindhyan rocks, but I have the positive assurance of the natives that diamonds have not been found in that river, although gold is and has been regularly washed for. On the other hand, diamonds have been found in the bed of the Mahanadi as far west as Chanderpur, and at other intermediate places, well within the area which is exclusively occupied by the quartzites, shales, and limestones of Vindhyan age.

The fact that the place, Hira Khund, where the diamonds were washed is on metamorphic rocks, may be readily explained by the physical features of the ground. The rocky nature of the bed there, and the double channel caused by the island, afforded unusual facilities for, in the first place, the retention of the diamonds brought down by the river; and secondly, for the operations by which the bed could on one side be laid bare, and the gravel washed by the simple contrivances known to the natives.

It is impossible to say at present which the actual bed or beds of rock may be from whence the diamonds have been derived, as there is no record or appearance of the rock ever having been

* By a few small streams which rise in an isolated outlying hill, called Gotwaki.

worked but from the general lithological resemblance of the sandstones and shales of the Barapahar hills, and the outlier at Borla, with the diamond-bearing beds, and their associates at Panna in Bhandelkand, and Banaganpilli in Karnul, I have very little hesitation in pointing to these rocks as in all probability including the matrix. Above Padampur, the Mahanadi runs through rocks of this age, and I should therefore strongly urge upon any one who may hereafter embark upon the undertaking of searching for diamonds in Sambalpur, to confine his operations, in the first instance, to the streams and small rivers which rise in the Barapahar hills, and join the Mahanadi on the south. Besides the obvious advantage of being—as I believe would be found to be the case—close to the matrix, these streams, would, I think, be found to contain facilities for obtaining a sufficient head of water for washing purposes. Such works would require but a few labourers, and could be carried on for a much longer period every year, say altogether for eight or nine months, than would be possible in the case of the washings in the bed of the Mahanadi itself.

According to the accounts received by me, the southern channel of the Mahanadi used not to be emptied in the Raja's time; but from various causes I should expect it to yield, proportionately, a larger number of diamonds than the northern. In the first place, the stronger current in it would be more efficient in removing the substances of less specific gravity than diamonds, while the rocks and deep holes in it afford admirable means for the retention of the latter. Owing to the greater body of water to be dealt with, it would be found to be more difficult to divert than that which flows in the northern channel; but the result in a greater harvest of diamonds would probably far more than compensate for the greater expenditure incurred.

In the country to the south of Sambalpur, in Karial and Nowagarh, where rocks of similar age occur to those of the Barapahar hills. I have failed to find any traditional record of diamonds having ever been found or searched for. It is just possible, however, that the names of several villages in which the word *Hira* (diamond) occurs, may have reference to some long-forgotten discovery.

In addition to diamonds—pebbles of beryl, topaz, carbuncle,

amethyst, cornelian, and clear quartz, used to be collected in the Mahanadi; but I have not seen either sapphires or rubies. It is probable that the matrix of these, or most of them, exists in the metamorphic rocks, and is, therefore, distinct from that of the diamonds.

Method of working.—From personal enquiry from the oldest of the Jhiras, or washers at the village of Jhunan, and from various other sources, I have gathered the following details as to the manner in which the operations were carried on in the Raja's time:—In the centre of the Mahanadi, near Jhunan, there is an island, called Hira Khund,* which is about four miles long, and for that distance separates the waters of the river into two channels. In each year, about the beginning of March or even later, when other work was slack and the level of the water was approaching its lowest, a large number of people,—according to some of my informants, as many as five thousand, Tavernier (vide supra) said 8,000 in his time,—assembled and raised an embankment across the mouth of the northen channel, its share of water being thus deflected into the southern. In the stagnant pools left in the former, sufficient water remained to enable the washers to wash the gravel accumulated between the rocks in their rude wooden trays and cradles. Upon women seems to have fallen the chief burden of the actual washing, while the men collected the stuff. The implements employed and the method of washing were similar to those commonly adopted in gold-washing, save only that the finer gravel was not thrown away until it had been thoroughly searched for diamonds. At least I was given so to understand, but Tavernier's account of this part of the process is probably correct. Whatever gold was found became the property of the washer, as already stated. Those who were so fortunate as to find a valuable stone were rewarded by being given a village. According to some accounts, the washers generally held their villages and lands rent-free; but I think it most unlikely that all who were engaged in the operations should have done so. So far as I could gather, the people did not regard their (in a manner) enforced services as involving any great hardship; they gave me to understand that they would be glad to see the annual search re-established on the old terms.

* *Lit.* Diamond mine.

Indeed it is barely possible to conceive of the condition of the Jhiras having been at any time worse than it is at present. No doubt the gambling element, which may be said to have been ever present in work of the above nature, commended it to the native mind. According to Mr. Emanuel, these people show traces of Negro blood, and hence it has been concluded that they are the "descendants of slaves imported by one of the conquerors of India." They are, however, I should say, an aboriginal tribe, showing neither in their complexions, character of their features, nor hair, the slightest trace of Negro orign.

When Sambalpur was taken over by the British, in 1850, the Government offered to lease out the right to seek for diamonds, and in 1856 a notification appeared in the Gazette describing the prospect in somewhat glowing terms. For a short time the lease was held by a European, at the very low rate of two hundred rupees per annum; but as it was given up voluntarily, it may be concluded that the lessee did not make it pay. The facts that the Government resumed possession of the rent-free villages, while the Raja's operations had been carried on without any original outlay, materially altered the case, and rendered the employment of a considerable amount of capital then, as it would be now, an absolute necessity.

Within the past few years statements have gone the round of the Indian papers to the effect that diamonds are now occasionally found by the gold-washers of Sambalpur. All my inquiries failed to elicit a single authentic case, and the gold-washers I spoke to and saw at work assured me that the statements were incorrect. Moreover, they did not appear to expect to find any, as I did not observe that they even examined the gravel when washing.

Weiragurh or Weiragud, eighty miles South-east of Nagpur.

This locality has not as yet been visited by any member of the Geological Survey, and information regarding it is scanty. The Rev. Messrs. Hislop and Hunter, in their well known paper*

* Journal of the Geological Society, Vol. xi., p. 355.

describing the formations of the Central Provinces of India, merely say that the matrix of the diamonds is a lateritic grit the only rock in its vicinity being quartzose and metamorphic. Hence they argue that Malcolmson,* and after him Newbold were wrong in inferring the identity of the sandstones of Central, with that of Southern India from the supposed occurrence of the diamond in the former, and they enlarge upon the supposed fact that most of the diamond-bearing deposits though resting on rocks of various ages are merely superficial and recent, and that therefore the diamond does not afford a safe guide for correlating the older rocks.

The whole discussion shows misconceptions on both sides which our present knowledge enables us perhaps to clear up. It is quite true that the sandstones of the Central Provinces which are referred to are not of the same age as the sandstones of Southern India which accompany the diamond-bearing strata, they are in fact very much younger, and Messrs. Hislop and Hunter were no doubt correct in asserting that the diamonds of the lateritic gravel had not been derived from them. But the mention of the quartzose metamorphic rock confirms what is independently probable, namely that the great basin of lower Vindhyan or Karnul rocks which occupies the upper portion of the Mahanadi valley stretches into the neighbourhood of Weiragurh, and it may therefore be suggested with a considerable degree of probability that the ultimate derivation of these diamonds is from a stratum occupying a horizon identical with that which constitutes the matrix of the Sambalpur diamonds, and as that in a general way has already been correlated with the diamond horizon in the Karnul rocks, the theories of both sets of observers contained hypotheses partly correct and partly erroneous the correct portions respectively supplementing one another. Malcolmson and Newbold were right in supposing that the diamonds of Weiragurh indicated the existence of rocks of the same age as those of Southern India (the Karnul formation), but were wrong in supposing that the fossiliferous sandstones which they referred to included the source of the gems. On the other hand Messrs. Hislop and Hunter while pointing out the

* Bombay Branch Royal Asiatic Society's Journal, Vol. I., p. 520.

latter mistake did not realise the existence of another formation close by from which the gems probably did originally come. They seemed to regard the diamonds both here and elsewhere throughout India as being a product of superficial deposits without reference to the nature of the beds upon which they rested.

When and by whom these mines were worked, and with what results, I cannot say, as I do not know of any published account of them. In the *Central Provinces Gazetteer* it is stated that "good sandstone and granite are obtained near the town; and mines of diamonds and rubies were formerly worked in the vicinity." The examination of the geological structure of this neighbourhood, and a comparison of it with that of Sambalpur, will, doubtless, be undertaken ere long by the Geological Survey. If the stratum which contains the diamonds should be identified, and if its lateral extension should prove equal to the known area occupied by the Vindhyan rocks, then we shall have a diamond-bearing tract probably greater in area than either those of Karnul or Bandelkhand.

CHUTIA NAGPUR.

As already stated above, on page 18, the upper portion of Ptolomey's *Adamas flus* passes through a district named Cocconage, which would include Chutia Nagpur. Independently of this, however, there are good reasons for believing that diamonds were found in Chutia Nagpur. The following notices on the subject I quote from a paper by the late Mr. Blochmann* :—

"Kokrah (the ancient name of Chutia Nagpur) was known at the Mogul court for its diamonds, and it is evidently this circumstance which led the generals of Akbar and Jahangiri to invade the district. I have found two notices of Kokrah in the Akbarnamah, and one in the Tuzuk-i-Jahangiri, from which it appears that Chutia Nagpur was ruled over in 1585 by Madhu-Singh, who in that year became tributary to Akbar. He was still alive in A.D. 1591, when he served under Man Singh in the Imperial Army which invaded Orissa. 'Tuzuk-i-Jahangiri (p. 155):—On the 3rd Isfandiarmuz of the 10th year of my reign (A.D. 1616) it was reported to me (Jahangiri) that Ibrahim Khan (Governor of Bihar) had overrun Kokrah and taken possession of its diamond-washings. This district belongs to *Subah* Bihar, and the river which flows through it yields the diamonds. When the river contains little water, tumuli and hollows are formed. The diamond-diggers know from

* Journal Asiatic Society of Bengal, Vol. xi.

experience that chiefly those tumuli contain diamonds over which insects hover, called by the Hindus *Jhingah*. They pile up stones on all sides of the tumuli, and then cut into them with hatchets and chisels and collect the diamonds from among the sand and stones. Sometimes diamonds are found of the value of a lac of rupees each. The district and the diamond river are in the possession of the Zamindar Durjan Sal. The governors of Bihar frequently sent detachments into Kohrah; but as the roads are fortified and the jungles impenetrable, the governors were generally satisfied with a tribute of two or three diamonds. When I appointed Ibrahim Khan Governor of Bihar, *vice* Zafar Khan, I told him at the time of departure to invade the district and drive away the unknown petty Rajah. No sooner had Ibrahim entered on his office than he prepared himself to invade Kokrah. The Rajah, according to custom, sent a few diamonds and elephants; but Ibrahim was dissatisfied, and invaded the district before the Raja could collect his men. When he received news of the invasion he was already besieged in the pass where he used to reside. Some of Ibrahim's men who had been sent out to look for him found him with several persons, among them his mother, another wife of his father, and one of his brothers, concealed in a cave. They were deprived of the diamonds in their possession. Twenty-three elephants besides were taken. . . . The district is now subject to me. All diamonds found in the river are forwarded to court. Only a few days ago a diamond arrived which had a value of 50,000 rupees, and I hope many more will be added to my store of jewels.' The diamond river alluded to is the Sunk."

To the present day a spot in the Sunk river is pointed out by the inhabitants as the place where the diamonds were washed for. In the year 1878 Captain Lowis, Guardian of the Chutia Nagpur Estate, pointed out to me this locality on the map.

Mr. Blochmann also gives a quotation from a history of the Maharajahs of Chutia Nagpur, in which is described a method of testing diamonds for flaws by affixing them to the horns of fighting rams, and states that—

"Jahangiri says the diamonds which Ibrahim Khan had brought from Kokrah had been given to the grinders. 'They were now submitted to me, and among them is one which looks like a sapphire. I have never seen a diamond of such a colour. It weighs several *rattis*, and my lapidaries fix its value at 3,000 rupees, though they would give 20,000 for it if it were quite white and stood the full test.'"

Colonel Dalton (Ethnology of Bengal, p. 163N), states that the Raja of Chutia Nagpur's family still possesses a diamond valued at 40,000 rupees, from these now fabulous mines. As illustrating the methods by which English officials in the olden time shook the pagoda tree, the following will be read with interest. In the

year 1772 the Raja appeared before Captain Camar, commanding a force in Palamow, and after exchange of turbans acknowledged himself as a vassal of the Company.

"In regard to this exchange of turbans," writes Colonel Dalton, "the family annals tell a strange tale. In the Raja's turban were some very valuable diamonds, which it is insinuated had excited the cupidity of Captain Camar. The proposal for the exchange emanated, it is said, from him. He declared it was the English method of swearing eternal friendship, but the Captain had no diamonds in his head-dress, and the Raja evidently concluded that he had been rather 'done' by the Company's officer."

In Gangpur the Icha river, which is a tributary of the Ebe, is marked on the Topographical Survey Map as being the site of diamond washings, but on what authority I know not. I have, however, myself heard the Ebe, near its sources, spoken of as the Hira (diamond) river.

Geology.—The geology of the localities on the Sunk and Icha rivers is not yet known. Possibly it may be found that there are outliers of the [Mahanadi-Godaveri] Vindhyan formation in their vicinity.

BANDELKHAND.

The writers who have described the diamonds and diamond mines of Bandelkhand, from personal observation are many,* besides them there are also not a few † who have written on the subject without having had the advantage of visiting the spot.

Franklin and Jacquemont, give ample details of the mode of working and extraction of the gems, their varieties, &c. The most recent contribution on this subject is by M. Rousselet; but for the geology reference should be made to the Memoirs by Messrs. Medlicott and Mallet of the Geological Survey of India, as the more popular writers have given currency to very incorrect views on this aspect of the question.

The following is an abstract of these geological accounts:—

* Franklin, Captain, "Asiatic Researches," Vol. xviii., p. 100; Jacquemont, M. V., "Voyage dans L'Inde," tome 1, p. 399; Adam, Dr., "Jour. Asiatic Socy., Bengal," Vol. xi., p. 399; Hamilton, Dr., "Edinburgh Phil. Jour.," Vol. i., p. 49; Medlicott, H. B., "Mem. Geol. Survey of India," Vol. ii., p. 65; Mallet, F. R., *ibid.*, Vol. vii., p. 113; Rousselet, M. "L'Inde des Rajahs," &c., &c.

† Carter, Dr., "Geological Papers on Western India"; Burton, Captain, "Quarterly Journal of Science," N.S., Vol. vi., 1876, p. 351.

The diamond bed proper, a conglomerate, belongs to a group at the base of the Lower Rewahs, * which is distinguished as the "Panna Shales," outlying patches of these rocks occur as remnants of old spurs and outliers from the tableland. Occurring thus without the usual covering of sandstone which is found on the flanks of the tableland, earlier observers were puzzled to account for the difference, and hence arose some of the confusion I have already described.

Mr. Medlicott gives the following account. At the time of his visit, the Panna miners had not got down to the diamond-bearing seam, which is not laid bare till about March in each year :—

PANNA.

"The rock diggings near Panna do not cover a surface of more than 20 acres, they are on a low, flat, rising ground at the base of the slope from the Kymore scarp; there were five or six pits in progress. The section is—three feet of soil, on a smooth surface of boulder clay; this latter contains large and small rounded boulders of sandstone, possibly the remains of masses fallen from the retreating cliff of the Rewah ridge; its thickness is very variable from two to twelve feet, due to the uneven surface of the subjacent rock; pebbles of the laterite iron ore are common along the bottom of the boulder bed.

"The top three feet of the hard rock looks more like a reconstruction of materials than a rock *in situ*. It is an irregular, streaked mass of clay, with occasional strings of broken grit bands, the crushing action which is so manifest in these upper layers extends itself to those below, contortion and fracture on a small scale are evident throughout," &c., &c.

These appearances are considered to be due to the falling of heavy masses of rock from the cliff face, which formerly existed, as it was undermined from below.

In the Panna mines, although the diamond seam is deeper than elsewhere, owing to the broken nature of the overlying strata it is not reached by a shaft, but the miners go to the immense labour of excavating great pits, 25 feet in diameter, and often over 30 feet deep for the sake of the small patch of diamond conglomerate thus uncovered. †

KUMEREA OR KAHMURA.

This locality which is situated to the east of Panna, was visited by Mr. Mallet, who describes it as follows. Here the matrix, locally called *Kakru*, is—

"A conglomeratic sandstone made up of pebbles, one-eighth to one-half inch diameter imbedded in a rather fine matrix which also includes clay galls. The lower Rewah sandstone here stretches out a consider

* *Vide supra*, p. 556. † *Vide infra*, p. 586.

able distance in front of the scarp, and the pit was just on the northern edge of this terrace, some 20 feet below the summit, and itself about 10 feet deep. On the top of the diamond bed was a foot or so of hard thin flaggy sandstone, and about seven feet of the same mixed with shale. A little further to the south and west on this terrace was an old pit between 30 and 40 feet deep, but the bottom filled with water, so that the rocks immediately above the diamond bed could not be seen, but there were certainly 10 to 15 feet of shale between it and the lower Rewah sandstone. In all the pits examined there must have been 10 to 20 feet of shale intermediate. The Pannas are here very thin, so that this position is not much above the top of the Kaimurs (the lowest group of the upper Vindhyans.) There are some small outlying hills to the north at the village of Bungla and north of Babupur. The former is about 50 feet high, with Kaimurs at the base, then 15 to 20 feet of shale capped in turn by the lower Rewah sandstone; this was the only outlying hill in which the shales were seen (on account of the northern overlap). A few hundred yards to the north-east, another little hill has been excavated in every direction by the old diamond searchers. Again at Babupur are numerous old pits, and some sufficiently well preserved to admit of examination. They are about 15 feet deep exposing sandstone with thin flaggy beds at the top, but no shales.

"A bed of fine, brown Sandstone, including fragments of a green silicious rock, and bits of red and green shale, was traced from Bumbhen to Kissengurh, which is not impossibly the continuation of the diamond bed; that the natives do not work to the east is no proof that the beds do not continue in that direction. This is evident from the fact of there being no pits at Bungla, notwithstanding the hills all round, even to the north, having been extensively worked.

"It is, therefore, almost certain that at Bungla the diamond bed exists though untouched."

Mr. Medlicott notices the transition of the conglomerate from its position among the shales to its condition as a pure, fine sandstone conglomerate.

In reference to the extension of the conglomerate, he remarks that from the nature of the case—its occurrence among fine beds—it has *per se* a precarious existence. He finds it difficult to determine the reasons why the deposit has not been worked in some localities, as at the base of the hills. In some cases, in the outlying patches, the margin of the deposit has been reached, in others it may have died out; the latter state of things might be readily ascertained were a few trenches dug in selected localities.

Mr. Medlicott makes some suggestions as to the original matrix of the gem, which I have already quoted. Besides the mines, he enumerates several localities where there were workings in accumulations of superficial detritus; these are at Udesna, Sakeriya, Mujgoan, and Boghin.

UDESNA.

The mines were being worked at Udesna:—

"There was water in all the pits, at what appears to be the level of the top of the boulder bed, under an irregular thickness of yellow clay, variously charged with kunkur and laterite gravel; the gangue is a stiff gravelly clay."

SAKERIYA.

"As at Udesna, there is a variable depth of clay, the middle third being kunkury and the lower lateritic; below this, the clay becomes charged with gravel, pebbles, and boulders, these rapidly increasing in size to great angular blocks of sandstone, scarcely moved from their original beds; it is from between these that the best stuff is got, a stiff unctuous clay, with quartz gravel through it. Above these deep pits, which are never far from the stream, and well up on the slope of the Rewah sandstone are diggings in the surface lateritic gravel."

MUJGOAN.

This, as suggested by Franklin, is probably the deserted gorge of a stream. Mr. Medlicott writes:—

"The filling in is certainly peculiar; the structure is like course foliation, a net-work of strings of calc spar, inclosing laminæ and small lumps of green clay.

"In the only hole I saw they were working the yellow clay from the crevices of this; but the men told me that at a greater depth there are alternating layers of green mud, and of its mixture with calc spar in which diamonds are found."

BOGHIN.

The mines of Boghin are thus described by Mr. Medlicott:—

"At the upper end of the gorge of the Boghin river there are two falls of 200 feet each, and there are workings throughout the whole length to Kalinjer. The principal diggings were at the lower end of the mine valley; they were removing some twelve feet of dark, brown clayey sand to get at the boulder bed, in the base of which the diamonds are found, but both here and below the narrow gorge the gravel at the surface of the river bed is much worked. The natives spoke to me of a European who, some twenty years ago, had made an attempt at mining on a large scale. His diggings were on the flanks of the limestone hill, some fifty or one hundred feet over the river, the ore being a jasper gravel gathered from the deep surface crevices of the limestone. As well as I could understand their pronunciation, the man's name was Berkeley, but I have not seen any written account of his experiment; the remains of his wash pits and picking floors are there still."*

* It is probable that the European referred to is the same as the one mentioned in the extract below.

Mr. Medlicott declines to believe in the instinct of the natives, as evinced by the capricious distribution of these surface diggings. There are many valleys in which the relation to the underlying rocks is such as to make it almost certain that the alluvial deposits contain diamonds, and yet there are no traces of workings. On the other hand, some of the workings prove the former extended range of the rock matrix which has been broken up by denudation. He believes further that the occasional occurrence of diamond-bearing deposits at higher levels than the original rock matrix may be accounted for by a distribution of the materials which took place under a general submergence of the country.

The following account of the Panna mines, which seems to be well worthy of reproduction, I have extracted from an Indian Newspaper. I am unable to give the author's name.

"The finances of the Maharaja are principally derived from his diamond and iron mines, and the following particulars as to how the mines are worked will prove interesting.

"In granting licenses to natives the invariable rule of the Raja is to restrict the claim to diamonds below six *rattis* in weight, on which a per-centage of Rs. 25 or upwards is charged. The party is then allowed to search in any spot within the territory, excepting such as are given to Brahmins for sacred purposes or are reserved for the Ranis or other relatives of the Chief. The mines of Kahmura and Panna are the most celebrated, and are excavated at a depth of 15 to 50 feet. They lie within the bounds of the rocky matrix. Those at Maggama have also been very imperfectly used, the mining not going below fifty feet, at which depth the water overflows, and the tuadars (or masters of the mines) are compelled to stop at this limit for want of a method to pump them dry. The *chila* and superficial mines are to be traced all over the diamond-tract, manual labour being cheap, as the poorest subjects of the State work them. From the commencement of the rains to the beginning of the cold season, the mining goes on, since a plentiful supply of water can be had in all parts of the State—an article highly necessary to facilitate the search, as the matrix, after being dug out, is placed by small quantities in a trench, and then washed to clear it of the clay which adheres to it. A spot on the surface of the mine is *leeped* smooth with the hand, and on it the granite is spread, and a diligent search made for the diamonds. Almost three-fourths of the people of Panna and the adjacent villages derive their living by working either for themselves or as hired labourers for others. When employed on their own account, it is not unusual to hear them complain of 'no luck for months and months.' Indeed, I never knew a native during the short time I was in the State, who said he had found a diamond, but I was told that the following is the way natives carry on when at the mines. The avarice

of the predecessor of the present Maharaja of Panna knew no bounds. The mines being the chief source whence his revenues were obtained, the native tuadars were never spared when they found diamonds, but had the most unreasonable taxes imposed upon them. This mischievous system and the impolitic rule that all diamonds above six *rattis* became the *bonâ fide* property of the Maharaja, seem to have engendered in speculators a vindictive spirit, not only to evade the heavy duties, but to cheat the State of the produce of the mines altogether. Every poor tuadar has a petty banker, who supports his constituents and his family with the necessaries of life, on the understanding that every diamond found by them should be sold to him, out of the amount of which he is to pay himself. In fact, a tuadar of the lower order is but an instrument to the Mahajans to rob the Maharaja, and it is a well-known fact that though these harpies hoard up wealth through the medium of their artful constituents, they will, on all occasions, in order to evade suspicion, plead poverty and distress, whilst they carry on a clandestine trade of diamonds between Mirzapur, Banaras, Allahabad, and Jabalpur. Some years ago, one of these Mahajans was detected in defrauding the State of diamonds to the amount of Rs. 43,000 for a long series of years. He was imprisoned and threatened with punishment, and to avert this, he refunded Rs. 16,000, and acknowledged having embezzled to the extent mentioned. It is well known that the Maharaja is robbed of large and valuable diamonds yearly. I believe only one European has ever tried working at the Panna mines, and this was in 1833, when a licence was granted him, and the following were the terms in his licence:—On diamonds of 1 to 7 *rattis*, 15 per cent. on the value; from 7 to 10 *rattis*, 33 per cent.; from 10 to 15 *rattis*, 50 per cent.; from 15 to 20 *rattis*, 66 per cent.; from 20 *rattis* and upwards, *bona fide* the property of the Maharaja, he having the option to reward the tuadars as he pleases. The expenses for working the mines at that time were as follow:—

For one month with 20 sets of labourers—

20 *bildars* at Rs. 2 per month,	Rs.	40
20 water women do.,	,,	30
4 sepoys at Rs. 3,	,,	12
Implements for digging, &c,	,,	40
Total	Rs.	122

It shows how cheap labour was in those days, whereas at this time *bildars* are getting Rs. 12 and 14 a month. The European (his name is not given, and I copy from an old Government record) says:—"In embarking in this enterprise, the chief evil to be guarded against is theft; a strict eye should be kept over the labourers during the hours of their work, as they not only pilfer and conceal these stones in the very mines they are working, but will, in cases of emergency, swallow them! It is said that before the British supremacy became paramount in these parts, delinquents of this description have suffered death rather than confess their having stolen the gems, which have afterwards been discovered in the ashes of their remains."

The early accounts by Franklin and Jacquemont have been perhaps to some extent supplanted by that by M. Rousselet. Captain Burton in his already mentioned paper gives the following abstract with some remarks of his own. While quoting from Captain Burton, I cannot omit to say that it is to be regretted that he should not have referred to the Official Geological Publications on the subject. Had he done so he would have seen that very much more has been accomplished with regard to fixing the horizon of the matrix and its distribution than he was led to suppose, and moreover, he would not have then rehabilitated several old theories which have been shown to be erroneous.

"M. Louis Rousselet ('L'Inde des Rajahs, Paris, Hachette, 1875), in his splendid volume pp. 440, 443, gives an illustration, and an account of the world-famous mines of Panna (the Panasca of Ptolomey?), a little kingdom of Eastern Bandelkhand erected in 1809. The Rajah sent a Jemadar to show him the diggings which are about twenty minutes' walk from the town. The site is a small plateau covered with pebble heaps, and at the foot of a rise somewhat higher than usual yawns the pit about 12 or 15 metres in diameter by 20 deep.

"It is found in alluvial grounds, divided into horizontal strata, *debris* of gneiss and carbonates,* averaging 30 metres; at the bottom is the diamond rock, a mixture of silex and quartz in a gangue of red earth (clay?). The naked miners descend by an inclined plane, and work knee deep in water, which the *noria* or Persian wheel, turned by four bullocks, is insufficient to drain; they heap the muddy mixture into small baskets which are drawn up by ropes, whilst a few are carried by Coolies. The dirt is placed upon stone slabs sheltered by a shed; the produce is carefully washed, and the silicious residuum is transferred to a marble table for examination. The workmen, each with his overseer, examine the stones one by one, throwing back the refuse into a basket; it is a work of skill on the part of both men, as it must be done with a certain rapidity and the rough diamond is not easily distinguished from the silex, quartz, jasper, limestone, corundum, &c.

"Tradition reports that the first diamonds of fabulous size were thus found, and the system of pits was perpetuated; when one is exhausted it is filled up and another is opened up hard by—a deplorable system, as 100 cubic metres must be displaced to examine one—and around each well a surface of twenty times the area is rendered useless. Moreover, much time is lost by the imperfect way of sinking the shaft, which sometimes does not strike the stone.

* What is intended to be conveyed by the term "carbonates" I cannot say since other than diamonds there are no traces of carbon in these rocks.

"This diamond stratum extends more than 20 kilometres to the north-east of Pannah. The most important diggings are those of the capital of Myra, Etawa, Kamariya, Brijpur and Baraghari. The mean annual produce ranges between £40,000 and £60,000, a trifling sum, as the stones are the most prized in the world and sell for a high price in the country.

"They are pure and full of fire; the colour varies from the purest white to black with the intermediate shades milky, rose, yellow, green, and brown. Some have been found reaching twenty carats, and the Myra mine yielded one of eighty-three which belonged to the crown jewels of the Mogul. Of course the real produce must be taken at double the official estimate. Despite all precautions such is the case everywhere. The Rajah has established an approximate average amount, and when this descends too low he seizes one of the supposed defaulters and beheads him or confiscates his goods.

"He sells his diamonds directly to Allahabad or Benares and of late years he has established *ateliers* for cutting; these are the usual kind—horizontal wheels of steel worked by the foot."

ON THE PROSPECTS OF DIAMOND MINING IN INDIA BY EUROPEANS.

As I have already related in each of the three great tracts at Chennur, at Sambalpur, and at Panna, attempts have been made by Europeans to mine for diamonds, but in no instance have their operations proved to be successful. How far success was deserved by the manner in which the operations were carried on, it is impossible to state. Regarding the question, however, from a general point of view, I think it is easy to see that there are many causes which must tend to have an unfavourable effect upon the success of undertakings of this nature.

In the first place, however, it may be well to premise that there is not the least ground for supposing that there has been any real exhaustion of the localities where mining is possible. On the contrary the result of the systematic geological examination of the different areas, has been to show that the diamond-bearing strata have a wider extension there than the actual miners could have ever supposed—though not so wide as some writers like Captain Burton have concluded, by a process of including the most distant localities in one tract, and then computing the total area.

That the ancient miners possessed and acted on a kind of rule of thumb knowledge of the characteristics of the diamond-bearing strata in different tracts respectively, is almost certain; but that they applied such knowledge inductively to distant

tracts is extremely doubtful. The probability is that in each neighbourhood operations were commenced in consequence of chance discoveries.

The following is a recent example culled from a newspaper:—

DISCOVERY OF A DIAMOND—The Collector of Karnul reported on the 17th December last, for the information of the Revenue Board, the discovery of a large raw diamond by one Mala Nagi of Karnul, one of the coolies employed in excavating earth in B. Class land of the Irrigation and Canal Company in Jaharapuram near Karnul. The diamond weighs 44 grains, and is said to have been purchased by Amboji, a merchant of Karnul, for Rs. 116. The real value is, of course, much higher, probably not less than Rs. 1,000. There are no diamond mines in Jaharapuram.

Prospecting far and wide we may be sure was never undertaken by natives, and it is doubtful whether there was any intercourse or communication between the workers at distant localities.

With scientific guidance, backed by capital and proper mining appliances, it may appear at first sight that mining by Europeans ought to succeed, but from what has already been said in reference to Bandelkhand, it will be gathered that there are in diamond mining certain peculiarities which distinguish it from most if not all other forms of commercial enterprise, the facilities for peculation in consequence of the readiness with which the gem may be conveyed is of course the principal of these. There must necessarily be a considerable amount of individual hand-work.

It would almost seem, in fact, that except under a system of slavery the diamond cannot be worked for profitably in India. The present system, though not so called, practically amounts to much the same thing, the actual operatives are by advances bound hand and foot to the farmers of the mines, and these are content to wait for months together without any return, their outlay too is very small, no heavy expenditure of capital being involved.

The case is in a measure parallel to that of manufacturing iron. The native iron-smelter, with no expensive plant, manages by a most wasteful process to keep himself alive by making iron. The English company turns out iron by the most approved methods, and after a time goes into liquidation. Such has hitherto been the case, but I am hopeful of the iron industry yet proving a success in India.

I would lay no particular stress on the fact that the several attempts in Southern India, at Sambalpur and at Panna, to work

mines under European management, have hitherto failed. These failures may have been due to causes with which the conditions I have above alluded to, have nothing to do, they may have resulted from simple incompetency, death, or sickness, &c.

My colleague, Mr. King, in writing of the South of India mines says, that it is not to be expected that diamond mining would, except by a mere chance, prove a rapid road to fortune. But for those content with a slowly paying occupation and a hard life, involving close personal supervision of the workers, it would pay, provided such persons possessed capital sufficient to last them some years.

NOTE ADDED IN THE PRESS.

I hope shortly to publish a paper on the correlation of the diamond deposits of the world. I think it advisable to attempt the task, since much that has been founded on erroneous data as regards India has been printed in connexion with accounts of Australian and African diamonds. Thus the late Rev. W. B. Clarke spoke of the diamond-bearing Banaganpilly strata as being of Mahadeva age.* Others have supposed that the diamonds of India were connected with the Dekan basalt.

* Anniversary Address. Trans. Royal Society of New South Wales, 1870.

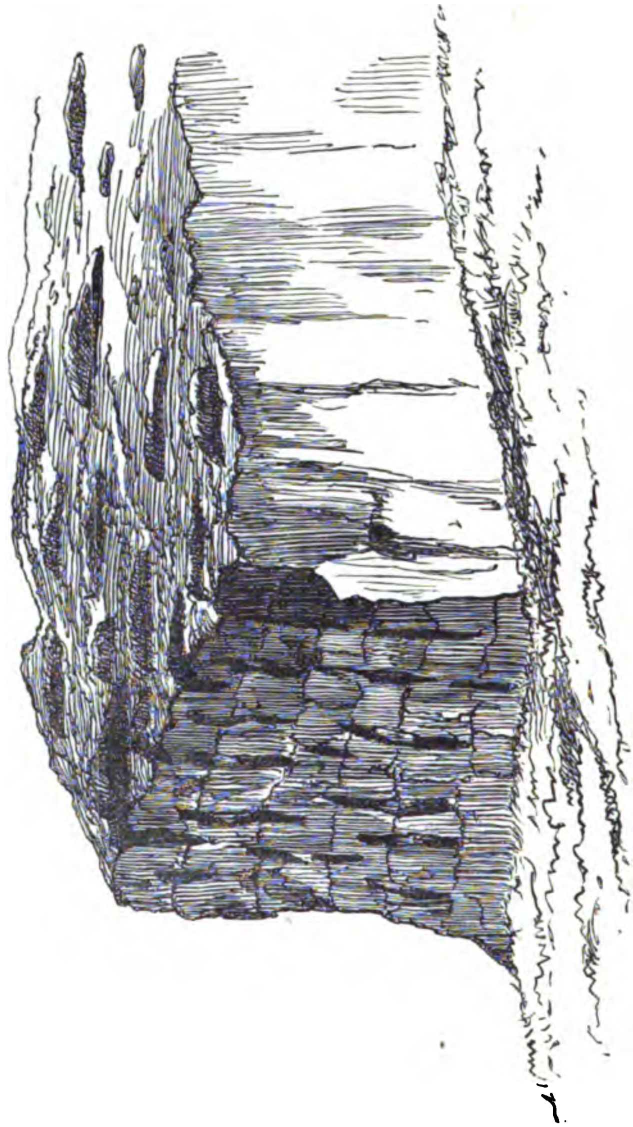
IV.—ON CHERT IN THE LIMESTONE OF KNOCKBEG, COUNTY FERMANAGH, BY THOMAS PLUNKETT.

[Read June 21st, 1880.]

CHERT occurs in a variety of forms in nearly all the limestone hills from Florence Court to the bold headland known as Ben Bulbin, a few miles north of Sligo, including Knocknarea, to the west of that town.

Occasionally it may be found in boss-like masses studded over the surface of the limestone. It sometimes assumes the nodular form, but it is most commonly found in thin bands or layers intercalated with the limestone beds.

Knockbeg, as its name implies, is a little hill or elevated rocky surface; it is composed of limestone containing nodules and bands of chert. There is a strip of ground at the south margin of the flat hill top, about twenty perches long, and from two to four perches broad, in which are found vertical sheets of chert passing up at right angles through the almost horizontal limestone strata, and projecting from two to four feet above the surface, resembling huge flags set on edge. At first sight one might imagine that this strip of ground had been a pagan cemetery, containing a number of mutilated "giants' graves." The rocky surface having been exposed to the weathering of ages the limestone has yielded more freely to atmospheric erosion than the sheets of chert, leaving the latter standing up in bold relief. These projecting ribs of chert generally run in a north-westerly direction, and are from three to twelve feet in length; a few, however, run due west; they are not continuous in regular lines but occur somewhat as represented in the diagrammatic sketch on the next page.



In the face of the adjacent escarpment there is a very good section of a vertical sheet of chert exposed; it measures seven feet vertically, and is four inches in breadth at top, thickening to eleven inches at the bottom, where it passes into the mass of rock beneath. Below this section, in the face of the cliff, horizontal layers of chert, as well as nodules of the same, may be seen.

During the process of disintegration the chert sheets, whether vertical or horizontal, weather in a similar fashion, some of the fragments which have crumbled off being rudely and irregularly prismatic, whilst others have come off in thin laminated plates. The character of the chert seems similar in all of the forms; this point, however, cannot well be determined without examination of sections under the microscope.

A question naturally arises here: were the vertical chert sheets formed simultaneously with the limestone in which they are found, or were they afterwards formed in fissures produced in the limestone when it became hardened, by siliceous matter which might have been washed into cracks in the mass of limestone? The evidence connected with them points to the former conclusion, viz., that they were formed simultaneously with the limestone.

There are adjacent rocks (part of the same formation) where chert is absent which attain a higher elevation, and which evidently extended at one time over the chert sheets in question, but whose extension has been removed by denudation. These elevated rocks form part of the adjoining cliff, and the beds composing them are in one unbroken sequence from bottom to top, and contain the fossils usually found in mountain limestone. The rocks containing the vertical sheets of chert, are exactly similar, and free from faults, cracks, or fissures. The horizontal and vertical sheets of chert appear to be one formation deposited in the bottom of the ancient Carboniferous sea. Still the question is not answered—how is it that some of the chert sheets are vertical?

V.—CORK ROCKS, BY G. H. KINAHAN, M.R.I.A., &c.

[Read, December 20th, 1880.]

When describing the Cork Rocks in the fourth chapter of the "Geology of Ireland," I pointed out that the Carboniferous rocks north of an irregular line drawn from Kenmare, county Kerry, to Passage West, Cork Harbour, have different relations to the underlying "Glengariff Grits" (Jukes) from those that are found to exist between the "Carboniferous Slate" and the "Glengariff Grits" (Jukes) south of this line; for while in the latter case there is a continuous sequence between the two, north of the line a similar sequence has nowhere been found.

On the north side of this line the proximity of the Carboniferous Limestone to the "Glengariff Grits" (Jukes) was pointed out by Griffith, Jukes, and their assistants, while the recent researches of Mr. M'Henry seem to prove that there is an undoubted unconformability between the older and newer strata. He has not, however, brought forward any evidence which proves an unconformability between the Carboniferous Slate of S. W. Cork and the "Glengariff Grits" (Jukes). On the contrary, all his work would seem to prove that Griffith and Jukes were right in stating that there was no unconformability or hiatus between these two groups of strata.

The reason for the unconformability between the Carboniferous rocks north of the previously mentioned line and the "Glengariff Grits" (Jukes) is a subject which as yet has not been properly considered or investigated, at first the problem may appear complicated, but if similar phenomena in action at the present day in different places are studied, the difficulty in a great measure disappears.

In north Europe, Scandinavia divides the Baltic from the seas to the westward. East of Scandinavia the sea bottom for a long period has been continually rising and sinking, while west of Scandinavia the sea bottom has been comparatively stationary. Consequently in the first area the different accumulations ought

to be more or less unconformable to one another, while in the latter all the strata should form a continuous sequence, and in the straits connecting the two sea areas, various complications partaking of the nature of the two different systems of accumulations might be represented.

Let it be supposed that a similar state of things to that now going on in the Scandinavian seas gradually had been in existence in the area now represented by Cork and the adjoining portions of Kerry and Waterford. *First,* the rocks now represented by those called by Jukes "Glengariff Grits,"* were accumulated over a large area. *Second,* along an irregular line from Dingle Bay to Kenmare, and thence to and beyond West Passage, Cork, a mass of country began to rise, and in connexion with it a spur of country extending from this line at Mangerton eastward for some distance. *Third,* in the area southward of the rising tract last mentioned the ground was stationary or gradually sinking so as to allow successive strata to accumulate on it; while northward of the rising ground, the land had already been rising before the accumulation of any new strata. *Fourth,* south of the irregular line the accumulations formed a continuous sequence, while northward of it including the tracts north and south of the spur of land extending east ward from Mangerton, the newer accumulations would lie more or less unconformably on the older. *Fifth,* east of about the longitude, of Cork, at the *hinge line* where the elevation adjoined the depression, there would be considerable complications, the accumulation of the two types being mixed and dovetailing into one another.

If the above suggestions are correct, northward of the line of rise, the newer rocks of the central Ireland Carboniferous type, ought to lie unconformably on the older in the following localities, viz., in the vicinity of Dingle Bay, at Killarney lakes, in the valley of the Flesk and Blackwater, at Kenmare, and in the valley of the Lee at Macroom, Coachford, Innishcarra, Blarney, and Passage West.

The localities just mentioned, beginning to the northward, give the following :—In the promontory of Dingle the Upper or

* It is necessary, for the sake of distinction, to connect Jukes' name with this group of rocks, as Prof. Hull has given a nearly similar name to a more extensive group of which these rocks form but a part.

Carboniferous Old Red Sandstone lies unconformably on the "Dingle beds," the representative of a portion of Jukes' "Glengariff Grits;" while south of Dingle Bay, between Doulus Head and Killarney, there seems to be a somewhat similar unconformability. In the neighbourhood of the middle lake of Killarney, in Glenflesk, and in the western portion of the Blackwater Valley, there is the great fault with a downthrow to the northward, but at the same time the Carboniferous rocks appear to be much nearer to the "Glengariff Grits" (Jukes) than they ought to be, if a regular sequence intervened between them; as, however, in the places where the sections are best exposed, the rocks evidently lie in inverted folds, nothing positive can be said as to the original relations of one group to the other. Further southward at Kenmare, and in the valley of the Lee, the relations between the Carboniferous Limestone, and the red and bright coloured older arenaceous and argillaceous rocks are very remarkable. As pointed out in the Geological Survey Memoirs and elsewhere, some miles westward of Kenmare in the neighbourhood of Sneem and Kilmackilloge, respectively north and south of Kenmare River, there are the "Carboniferous Slate," the upper member of the sequence that extends downwards conformably into the "Glengariff Grits" (Jukes); but in the neighbourhood of Kenmare there is a conspicuous difference as red rocks, not to be found to the westward, or in the country to the S.W., suddenly make their appearance, and associated with them are the rocks called Lower Limestone Shale, and the Lower Limestone; these red rocks appear to lie conformably on the "Glengariff Grits" (Jukes), but it is questionable whether the Lower Limestone Shale and the Limestone lie conformably on them or not. Further eastward in the valley of the Lee, at Macroom, Coachford, Innishcarra and other places, the Carboniferous Limestone seems to lie nearly directly on the "Glengariff Grits" (Jukes). In these different places "Lower Limestone Shale" is associated with the Limestone, and in the maps it is generally represented as encircling the different masses of the latter, this, however, seems to me to be improbable, as the Lower Limestone Shale is essentially a littoral accumulation and consequently must have only accumulated in those portions of the different areas where the con-

ditions were favourable for its being deposited, such as shallow bogs and the like. In connexion with these outliers of Carboniferous Limestone "Lower Limestone Shale," *in situ*, has been observed in places, but in others no trace of it can be seen; and apparently it is altogether absent, the limestone lying directly on the older rocks.

The rocks in the valley of the Lee, would seem to suggest a solution of the difficulty at present felt in reference to the difference in the arrangement of the rocks north and south of the previously mentioned irregular line between Kenmare and Passage West (Cork Harbour), as hereabout the newer rocks evidently were deposited in a valley margined with high cliffs of "Glengariff Grits" (Jukes); but the rocks in the Kenmare valley are so peculiar that before offering an opinion on them they would require a very careful examination.

In the vicinity of Cork Harbour, is the locality of the *hinge line*, between the depression and elevation where the rocks of *the Central Ireland type*, and of *the Cork type*, meet and intermingle. Consequently from Cork Harbour eastward to the sea near Dungarvan, the rocks in the sections may be of either types, or of the two types mixed up together, while in places they seem to lie unconformably on the "Glengariff Grits" (Jukes).

The "Glengariff Grits" also seem to be changing eastward, and I suspect that the rocks of the Commeragh mountains (conglomerates, &c.), although lithologically different, yet eventually will be found to be the littoral accumulations of the "Glengariff Grits" (Jukes).

VI.—ON THE GEOLOGICAL STRUCTURE OF THE NORTHERN HIGHLANDS OF SCOTLAND; BEING NOTES OF A RECENT TOUR, BY EDWARD HULL, LL.D., F.R.S., DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND. PLATES 1, 2, AND 3.

[Read, December 20th, 1880.]

The following notes were made during a tour in the North Highlands of Scotland during the spring of 1880, under the guidance of Professor Geikie, Director of the Geological Survey of Scotland, in company Mr. R. G. Symes, of the Geological Survey of Ireland, and several other friends; the object being to observe the character of the geological formations of that district, with a view to a comparison with those of the north-west of Ireland, where the operations of the Survey are about to commence.*

The author could not hope to be able to communicate much information (if any) absolutely new, but the physical features and geological phenomena proved of such interest, and of so remarkable a character that he hoped a brief outline of his observations would not prove unacceptable.

The course taken was as follows:—Reaching the village of Garve, near Dingwall, by the Highland Railway, the road lay right across that part of Scotland to the head of Loch Broom and Ullapool, through the beautiful glens of Braemore, which open on the head of Loch Broom. Thence to Inchnadamff, which lies at the head of Loch Assynt, and close to the base of Ben More, Canisp, and Quenaig. Thence to Scourie and Rhiconich, which is only a few miles distant from Cape Wrath, and then across Scotland to Lairg, where the railway to the south was reached. By this route two traverses across the country, at a distance of about thirty miles from each other, were made, and the western coast for a distance of about fifty miles was examined.

The geological structure of this district has only recently been clearly and definitely demonstrated by the researches of the late

* This visit was an official one, made with the sanction of the Director-General.

Sir R. I. Murchison,* following on the discovery by Mr. Charles Peach, of Lower Silurian fossils in the Durness and Assynt limestone (1854). Previous to that period the crystalline schists of the Central Highlands were considered to be of "primary" age; and the red sandstones and conglomerates of the north-west coast were supposed to be of the same geological age as those of the north-east coast—namely of "Old Red Sandstone" age.

Sir R. I. Murchison demonstrated that the red sandstones and conglomerates of the west lie beneath all the crystalline schists, quartzites, and limestones of the Central Highlands, to which they are unconformable,† and as the latter are shown, by the fossils found in the Assynt (or Durness) limestone, to be of Lower Silurian age, the underlying sandstones are inferred to be representatives of the Cambrian, and the fundamental gneiss and schists, which underlie the Cambrian, are also inferred to be representatives of the Laurentian group of Canada, which lies at the base of the Cambrian and Silurian rocks of that country.

The general section may be stated as follows :—

FORMATIONS OF THE NORTHERN HIGHLANDS.

Lower Silurian Beds, probably from 7,000 to 10,000 feet.

	Approximate thickness in Feet.
(*a.*) Gneiss, quartzite, mica-schist passing down into the Upper Quartzite of Benmore in Assynt, . (over)	5,000
(*b.*) Ribband glossy slates and flagstones, . . (about)	500
(*c.*) Assynt limestone—upper part yellowish and dolomitic in places; lower white, and full of cavities like casts of fossils, but rarely with fossils themselves, . .	100 to 1,000
(*d.*) Ferruginous sandy flags, shales, and bands of limestone, containing "fucoid" markings, ...	100 to 200
(*e.*) Lower Quartzite; purple, grey, and white quartzite, the upper beds penetrated by annelid burrowings, .	500 to 1,000
(Great hiatus and unconformity.)	

Cambrian Beds.

Red and purple sandstone, sometimes pebbly, and towards the base passing into a conglomerate, with large pebbles and blocks of quartz, quartzite, jasper, felstone, gneiss, &c., in thickness from	0 to 3,000

* Quart. Journ. Geol. Soc., London, vols. xv. and xvii., 1858-61.

† "Siluria," 4 Edit., p. 163, with section p. 169. Figures of the fossils are given by Murchison; they consist of Maclurea, Ophileta, Oncoceras, and Orthoceras.

Laurentian Beds.

(*a*.) Upper part; hornblende schist, hornblende gneiss, and hornblende rock, sometimes micaceous, and penetrated by quartz veins, ... (*b*.) Lower part; reddish gneiss, penetrated by veins of granite or "pegmatite,"	Of great but uncertain thickness (*over* 20,000 *feet.*)

The above may be regarded as the general succession of the rocks about Loch Assynt, and as far as Loch Broom towards the south, and Loch Laxford towards the north.

It need hardly be stated that within this compass the beds vary much in thickness;—but not in character.

Throughout this region, and as far as the shores of Loch Dow, the Cambrian beds often rise into isolated precipitous hills or break off in grand escarpments and precipices, formed of nearly horizontal beds, rising tier above tier to elevations of 3,000 feet or upwards. Amongst the most remarkable is the north shoulder of Quenaig (Plate I., fig. 3), which rises in the form of a great terraced buttress of red sandstone, its sides cut into deep gullies by mountain torrents, and accessible only by stiff climbing. The western shoulder of Suilven, as seen from the banks of the ferry at Kylesku, the remarkable escarpment of Benmore Coygeagh, (Plate I., fig. 2), and the isolated truncated pyramid of The Stack (Plate I., fig. 1), are all instances of the results of denudation, acting upon masses of horizontally bedded sandstone, in producing bold and massive scenery—differing in character from that of any of the formations either above or below.

On reaching the Inn of Aultguish we came in sight of the mountains of Cambrian sandstone, at a distance of about ten or twelve miles to the westward, seen through a gap in the schistose rocks, and rising above Loch Broom in massive terraces; the horizontal stratification being clearly discernible by the aid of the binocular glass. The winter's snows still lingered on the summits and on the surfaces of the upper terraces. In front of them were the quartzite mountains of Ben Dearig and the neighbouring heights, generally capped with snow, which rise in bold rounded masses to an elevation of 3,551 feet.

On descending towards the head of Loch Broom, along the valley of Braemore, we visited one of the most remarkable river gorges in the British Isles—a veritable

miniature cañon (Plate II., fig. 6), hewn by the mountain torrent out of slightly inclined beds of quartzite. Crossing on to a pretty little suspension bridge, thrown across the gorge by Mr. Fowler, C.E., 60 feet in width, we looked down on the bed of the stream below, at a depth of 222 feet—that is, over three and a half times the width of the chasm at the spot where spanned by the bridge. We could follow with our eyes the chasm for a considerable distance above and below the bridge—the sides bounded by nearly vertical walls of quartzite, decorated with a natural growth of ferns, shrubs, and climbing plants—to the rapids by which the torrent descended from a loch situated higher up the glen. Looking down the stream, the chasm could be followed for about a mile before it opened out on the wide glen of Braemore.

This miniature cañon is itself situated in a much wider valley, bounded by mountains of quartzite, and in excavating it the stream has been facilitated in its operations by numerous nearly vertical joints, represented in Plate II., fig. 6, traversing the beds of quartzite in the direction of its course, as well as by smaller joints and fissures crossing these at obtuse angles.

On descending along the shore of Loch Broom, we observed the horizontal beds of Cambrian sandstone, about 3,000 feet in thickness, appearing from below the inclined beds of quartzite on the southern banks; and at the bridge of Ault Corry crossing a burn, about a mile from Ullapool, we had an opportunity of examining the "Assynt limestone," here only ten feet in thickness, for the first time, (Plate II., fig. 7).* Just outside of Ullapool we passed a bluff, showing the superposition of the lower quartzite on the red sandstone and conglomerate of the Cambrian formation, with a clear unconformity in the stratification. We had thus in our first day's journey made a transverse section of the Lower Silurian metamorphic series of the Northern Highlands. It seemed clear to us that notwithstanding some slight fissures, some faulting, and possibly local foldings or inversions, we had traversed a gradually descending series of highly metamorphised beds of quartzite, gneiss, and schist, down to less highly altered beds in contact with the Cambrian, inasmuch as the Assynt limestone and the associated shales and flagstones could scarcely be recognised as having undergone metamorphic action. This was pointed out to

* Murchison and Geikie, Quart. Journ. Geol. Soc., vol. xvii., p. 184.

us by Professor Geikie, and was readily acknowledged by his fellow travellers.

On the second day our route from Ullapool to Inchnadamff, a distance of twenty-six miles, lay along a tract of country bordering the Silurian and Cambrian formations. We passed under several grand escarpments of Cambrian sandstone; the most remarkable being that of Benmore Coygeagh (Plate I., fig. 2), which faces the south, and terminates abruptly on the side next the ocean. The cliffs of horizontal sandstone rise to a height of about 3,000 feet, and are worn into deep gullies by the action of torrents. Nevertheless, the face of the escarpment rises like a great wall of red sandstone from the crest down for a thousand feet, where the slopes commence. A short distance further north we came in view of "The Stack," an isolated mass of Cambrian sandstone, (Plate I., fig. 1) also in horizontal beds; and, beyond, the heights of Coulmore* and Coulbeg, the former capped by the lower quartzite of the Lower Silurian series.

Throughout this tract the "Durness Limestone" became more and more conspicuous as we proceeded northwards; its thickness increased till, on approaching the head of Loch Assynt, it expanded to about 1,000 feet, and rose in a conspicuous escarpment above the foot of the quartzite slope at the eastern base of Canisp. The presence of the limestone amongst the hills and valleys is marked by a band of verdure in the midst of the sterile tracts of heather formed by the quartzites both above and below. The limestone is generally weathered as white as chalk, but in some places contains beds of dolomite weathering rusty brown. It is but very slightly altered, and frequently contains cavities exceedingly like those left by fossil shells; but with the exception of an *Orthis* (?) found by Mr. Symes, we did not succeed in obtaining a single specimen of organic origin.

On approaching Inchnadamff we skirted the eastern base of Canisp. This is an escarpment of Cambrian sandstone capped by quartzite, rising in a grand mural cliff facing the Atlantic. It terminates abruptly along the shore of Loch Assynt, and from the north shore of the loch the whole structure of the mountain is clearly revealed. The lower quartzite is seen to descend with a

* Coulmore, together with Canisp and Suilven, are represented in one of the illustrations in Murchison's "Siluria," 4 Edit., p. 170; and are graphically described by Hugh Miller.

gentle slope across the truncated horizontal beds of Cambrian sandstone till the latter is cut out altogether, and the base of the Lower Silurian series rests directly upon the Laurentian gneiss.* The section (Plate III., fig. 9) taken across Quenaig, on the north shore of Loch Assynt, shows a similar structure amongst the formations.

This disappearance of the Cambrian beds as we proceed northwards is a remarkable feature in the physical geology of the district. The abrupt truncation of the sandstone at the edge of the Silurian quartzite, leaves no doubt that the formation was enormously denuded, even before the Lower Silurian beds began to be formed. At that period, however, the beds were tilted towards the west. Their present horizontal position being in consequence of the tilting towards the east of the Silurian beds.

On approaching the deep inlet called Loch Dhu (or Dow) and the ferry of Kylesku, we passed near the base of the grand precipices along which Quenaig terminates towards the north. The bold bluffs of Cambrian sandstone rise about 2,000 feet, and form certainly the noblest cliffs I had seen (Plate I., fig. 3.) Notwithstanding the great thickness of the formation (about 2,000 feet) in Quenaig, the whole had actually disappeared under our feet; and we could trace the Silurian quartzite margin resting directly upon the dark hornblendic schists of the Laurentian formation which extends from the base of Quenaig to the coast, and to the shores of Loch Dhu.

From Kylesku to Scourie our course lay over a tract of broken and comparatively featureless country, highly glaciated by an ice-sheet which had moved towards the Atlantic. The rocks belong to the Upper Laurentian series, are chiefly hornblendic, highly crystalline in structure, schistose, and gneissose; occasionally schist of bronze mica was observed. Quartz veins are of frequent occurrence, and the beds are slightly crumpled. These rocks we had a good opportunity of examining during our last excursion northwards, on the following day, when we drove from Scourie to Rhiconich, a distance of twelve miles, the whole over Laurentian rocks.

Our course lay over an exceedingly rugged country, with numerous little lochs, rock-basins, gullies, and deep ravines. Everywhere the rocks were exposed to view, presenting remarkably ice-worn surfaces, often strewn with boulders of quartzite and

* The scenery at the head of Loch Assynt forms the Frontispiece to "Siluria" 4 Edit.

of other rocks from the interior mountains. There is no mistaking the direction of the ice movement, which has here been westward; but it is only in protected spots that boulder clay, or moraine matter, is to be found. In general the rocks are bare to a remarkable degree, the ice having apparently swept the loose materials out into the ocean.

On this day we passed under Ben Stack (Plate II., fig. 4), a pyramid of dark Laurentian hornblendic gneiss, rising 2,364 feet above the sea, and the highest elevation (as I was informed by Professor Geikie) to which the Laurentian rocks rise on the mainland. We were also close under the escarpments of Ben Arkle (Plate III., fig. 8) and Foinaven, the former 2,576 feet, and the latter 3,016 feet. These are formed of Laurentian beds, capped by Lower Silurian quartzite,—the whiteness of the latter contrasting with the dark tints of the former. As already stated, the Cambrian sandstones have been entirely denuded away over this part of the country previous to the deposition of the Lower Silurian beds. The section (Plate III., fig. 8) may be compared with that across Quenaig (Plate III., fig. 9), in order that the changes in the stratification and physical features may be better understood.

It should be observed that throughout the district we examined, the lower quartzite at the base of the Silurian series generally crops out as an elevated escarpment, towards the south, capping unconformably the Cambrian sandstone; towards the north, the Laurentian gneiss. As this escarpment crosses transversly the general drainage of the country, and the course of those rivers which rise in the interior and flow westward towards the ocean, it is intersected by deep and wide valleys, so that it is exceedingly broken, and the lines of cliff run far up the valleys towards the east. Coulmore, Canisp, Quenaig, Ben Arkle, and Ben Foinaven are all situated on the margin of the lower quartzite.

On the other hand, the upper quartzite rises into equal, or still higher elevations such as Ben Dearig, Ben More in Assynt, Ben Hee, and Meal Horn, and generally forms the watershed of the North Highlands. The Cambrian beds generally form isolated, or partly detached masses. In no district I have ever visited do the physical features give more clear expression to the geological structure than in the North Highlands of Scotland.

The Laurentian rocks extend all the way from Scourie to Rhiconich and Laxford Bay, and from thence to Cape Wrath.

On leaving Scourie, we pass transgressively over a descending series of hornblendic beds, sometimes micaceous, belonging to the upper part of the series. Sometimes the crystals of hornblende are here two inches in length. At Loch Naclaishfearn the beds are highly micaceous and garnetiferous. At the head of Loch Laxford we pass into the lower series, consisting of gneiss, well foliated, of red felspar, quartz and mica. Veins of pegmatite become more frequent as we proceed, and in crossing Laxford bridge, on the road to Rhiconich, fine sections are laid open in beds of gneiss penetrated by numerous dykes and veins of pegmatite (a kind of granite), consisting of red orthoclase, crystals of pale yellowish or grey oligoclase, often of large size and showing the fine parallel lines which characterize a triclinic felspar. Along with the above are quartz and green mica. The pegmatite veins traverse the gneiss and schists in all directions, sometimes vertically, at other times obliquely, and cross the planes of foliation. They have been noted by Murchison as characteristic of the Laurentian beds; but it is chiefly in the lower portion they become conspicuous. About Rhiconich, the dip of the beds is southwards or S. S. W., at various angles; and as this dip was more or less prevalent all the way from Scourie, I estimate that the Laurentian beds must be over 20000 feet in this district;—how much more no one can say as the base never appears.

As we returned to Scourie by sea, we had an opportunity of surveying the coast cliffs of red gneiss, and had a fine view of Suilven, Canisp, and Quenaig towards the south, rising from a rugged plateau of Laurentian beds. The horizontal beds and terraces of red sandstone were easily discernible, even at the distance of over twenty miles.* The white dome of Ben More, and its adjoining quartzite ridges of Ben Arkle and Foinaven, bounded the horizon towards the west, while Ben Stack rose above the head of Loch Inchard (Plate II., fig. 4), which we were leaving behind, in the form of a dark shapely cone. Looking northwards over the heaving surface of the Atlantic we could see the islands of Ellen-a-Vullig in the direction of Cape Wrath.

On the day following (2nd June) we left Scourie and again crossed the North Highlands from sea to sea, reaching the rail-

* See View of these Mountains in Ramsay's Phys. Geol., Gt. Britain, 5 Edit., p. 288

way at Lairg. The road lay along the valley of the Laxford, and by the banks of Loch Stack, Loch More, and Loch Shin, crossing the low watershed under Ben Hee. As far as regards this journey I have only to observe that we had an opportunity of observing the general succession of the beds from the lower quartzite upwards through the limestone series, the upper quartzite, into the metamorphic schists, and that, with occasional undulations in the stratification, there appeared to be a continually ascending series till we reached the granite of Lairg. Thus the results arrived at in reference to the succession of the beds between Scourie and Lairg were found to correspond with those arrived at by the more southerly traverse between Garve and Ullapool.

Do Pre-Cambrian beds re-appear in the Central Highlands? The question has been asked and answered in the affirmative by some geologists, "Do the Laurentian (or pre-Cambrian) rocks re-appear in the Central Highlands of Scotland after disappearing below the Cambrian sandstones and Lower Silurian quartzites of the western districts?" As far as the observations which we were enabled to make are calculated to throw light on the question, I can only state my own impression, that the evidence is against this view. Throughout the districts of Sutherland, Ross, and Cromarty which we visited, it was clear that the Laurentian beds must be buried at enormous depths underneath the Lower Silurian beds the further we proceed eastwards from the outcrop. It is quite possible that the whole of the Cambrian sandstones may be absent under the centre of the North Highlands. From the direction in which these rocks disappear through the effects of denudation, it was evident that even at a short distance below the upper quartzite they might be absent even when they were in greatest thickness at the western outcrop. The sections at Canisp and Quenaig are very suggestive of this. Therefore we may well suppose that under the centre of the North Highlands the Lower Silurian beds rest directly on a Laurentian floor; and it seems to me highly improbable (though possible) that these latter rocks reappear at the surface, as there is clearly an ascending series all the way from the west towards the east of that part of Scotland. In the above statement I only refer to the region north of the Caledonian canal. Until the geological survey of the Grampian range throughout the Inverness and Aber-

deenshire Highlands is completed, it will be impossible to affirm positively whether or not Laurentian beds actually reappear.*

The two Unconformities. Bearing upon the geological history of this region, there is nothing more remarkable than the occurrence of the two unconformities,—the lower, between the Laurentian and Cambrian beds, and the upper, between the Cambrian and Lower Silurian series.

Both of these are of the most trenchant description. The abrupt truncations, and the sudden change of characters in the beds lying on either side of the boundary lines, suggest long intervals of time and great changes in the physical conditions under which deposition took place.

In the first place, the Laurentian beds were metamorphosed, contorted, elevated out of the sea-bed, and denuded, before the Cambrian beds began to be spread over the uneven floor thus constructed. Professor Ramsay considers the Cambrian sandstones to be of fresh water or lacustrine origin,† and that glacial conditions were to some extent prevalent during their formation.‡ A large proportion of the pebbles and blocks found in the Cambrian beds is composed of fragments torn from the Laurentian masses.

Of the Cambrian formation it is clear that only a fragment now remains in the North West Highlands. Its base is often visible, but its original upper limit never. It bears evidence of the effects of at least two great denudations. The first before the deposition of the Lower Silurian beds; the second at a later period, probably often repeated, and coming down to recent times. The great buttresses of horizontal sandstone—against which the Lower Silurian beds rest—may be regarded as the eastern margin of continental land of the Lower Silurian period, embracing the outer Hebrides, and an unknown region beyond.‖ At that period the Cambrian sandstones were tilted and the Lower Silurian beds

* The only rock resembling Laurentian which we noticed in the central districts was a remarkable massive red gneiss, at Inchbrae, seven miles from Garve, in a N. W. direction, on the Ullapool road. This gneiss consists of red felspar, black mica, a little quartz and epidote. As far as its composition is concerned, it might be of Laurentian age; but in position it appears to be high up in the Silurian metamorphic series.

† Phys. Geol. and Geog., Gt. Britain, 5 Edit., p. 285.

‡ Pres. Address, Brit. Assoc, Rep. 1880, p. 17. This view is founded on the discovery by Professor Giekie of glaciated surfaces of Laurentian rock passing underneath Cambrian sandstone at intervals all the way from Cape Wrath to Loch Torridon, together with large blocks of gneiss in the Cambrian bed.

‖ Ramsay, Phys. Geol. and Geog., p. 87.

were in approximately horizontal positions. The case is different now, for the Silurian beds have an easterly dip, while the Cambrian sandstones are nearly always horizontal. It is clear, therefore, that the present horizontality of the latter is due to a second tilting in a direction opposite to the first. In the accompanying diagram (Plate II., fig. 5) I have attempted to restore the beds of the three formations to their positions at the time the Lower Silurian rocks were in their original horizontal position. It will be observed that *then* the Cambrian rocks had a dip westward, while the original denuded surface of the Laurentian schists sloped at a smaller angle in the same direction.* Upon this horizontality of the Cambrian beds depends in a large measure the peculiarities of the west Highland scenery, and it is doubtful if a stranger series of events in stratigraphical geology is to be found in any other part of the world.†

Do Laurentian Rocks occur in the North or West of Ireland? All that one can say at this moment is, that the district lying north of Galway Bay in Connemara, Belmullet in Mayo, and parts of northwest Donegal contain beds of gneiss similar in appearance and composition to those which constitute the Laurentian beds of Sutherlandshire, and that these beds stand in some sort of relationship to the recognized Lower Silurian metamorphic beds consisting of quartzites, limestones and schists. But until the Highlands of Donegal have been thoroughly explored by the officers of the Geological Survey, and the relations of the beds clearly established, no positive answer can be made to the above question, the Cambrian beds being (as far as we know) unrepresented.

* From this diagram, which was made at Quenaig (see Plate III., fig 9), not being drawn strictly to scale, I cannot be certain that the slope of the Laurentian floor is correct.

† The peculiarities of this district have been described by Macculloch, Hugh Miller, Murchison, Ramsay, Geikie, and others.

‡ The author proposes to make a preliminary examination of the Donegal Highlands during the ensuing summer with a view to determine the question here raised.

FIG 4.

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 1.

FIG. 2.

FIG. 3.

REFERENCE TO PLATES.

PLATE I.

Plate I. Fig. 1. This is a drawing of "The Stack," which, with its neighbours Coul Beg and Coul More, consists of nearly horizontal beds of Cambrian sandstone and conglomerate, resting on a floor of Laurentian schist and gneiss. The position of this isolated mass is inland from Lough Enard in Cromarty.

Plate I. Fig. 2. Represents the grand escarpment of Benmore Coygeagh, in Cromarty, also consisting of horizontal beds of Cambrian sandstone, breaking off in precipices towards the south and west. The rocks of the foreground are of the same formation, and have an eastward dip. The view is taken from the shore of an inlet from Loch Broom, looking north.

Plate I. Fig. 3. Represents the great buttress of Cambrian sandstone, in nearly horizontal layers, along which Quenaig ends off towards the north. From the base, the Laurentian floor from which the sandstone beds rise, stretches away northwards and westwards in a rough boulder-strewn tract to the shores of the Atlantic and the dark inlet of Kylesku. The manner in which the lower quartzite of the Silurian series stretches over the denuded edges of the Cambrian sandstones is represented in section, Plate III., Fig. 9.

PLATE II.

Plate II. Fig. 4. Ben Stack in Sutherlandshire, seen from the entrance to Loch Inchard. This is a remarkably symmetrical cone of Laurentian hornblende schist, rising 2,364 feet above the Atlantic. The bedding, as also the system of joint planes by which the rock is traversed, are clearly visible, and their relationship to the outline of the cone will be recognised at a glance. The shores of Loch Inchard are composed of the red gneissose beds underlying those of Ben Stack.

Plate II. Fig. 5. This is a diagram to illustrate the point to which I have drawn attention (p. 11), that at the time the Lower Silurian beds (s. 1) were being deposited in a nearly horizontal position, the Cambrian sandstone (c.) of the district around Loch Assynt must have had a westerly dip. Upon the upheaval of the former, and on its assuming an easterly dip, the Cambrian beds were placed in their present position of approximate horizontality.

Plate II. Fig. 6. Is a section, drawn to scale, of the deep gorge or cañon of Braemore, at the head of Loch Broom. The nature of this remarkable river-channel has already been sufficiently described.

Plate II. Fig. 7. The section at the Bridge of Ault Corry, near Ullapool, in which the following beds in descending order are seen—all of the Lower Silurian series:—

S. 5.—Hard, massive, reddish pebbly grit at the base of the upper quartzite—6 feet thick.

S. 5'.—Whitish quartzite in regular beds—4 fect thick.

S. 4.—Thin band of shale and flags.

S. 3.—Limestone in several beds with bands of shale—6 to 10 feet.

S. 2.—Grayish sandy shale with fucoid markings.

S. 1.—Upper beds of lower quartzite.

General dip, E.S.E. at 5 to 6 degrees.

PLATE III.

Plate III. Fig. 8. Section taken across Ben Stack and Ben Arkle. The former 2,364 feet, the latter 2,576 feet in elevation; direction about W. to E.

Ben Stack, as already stated, is formed of dark hornblendic schists, &c., of Laurentian age (L), penetrated by granite or pegmatite veins. The Cambrian sandstone being here absent, the Laurentian beds are immediately overlaid by the lower quartzite (s. 1) of the Lower Silurian series, forming the escarpment of Ben Arkle; this is followed by ferruginous sandy shales, with fucoids (s. 2), then by the Assynt limestone (s. 3), the glossy slates and flagstones (s. 4), the upper quartzite (s. 5), and finally by the micaceous schists of the interior (s. 6), at the margin of which the section ends.

Plate III. Fig. 9. Section drawn across Quenaig, 2,240 feet, and Ben More in Assynt, 3,281 feet, and passing a short distance to the north of Inchnadamff. This shows the basement hornblendic schists of Laurentian age (L), overlaid by Cambrian sandstone and conglomerate (C), the beds of which are truncated along the eastern side of Quenaig by the lower quartzite of the Lower Silurian series. The succeeding beds are lettered and numbered as in the preceding section.

FIG. 8

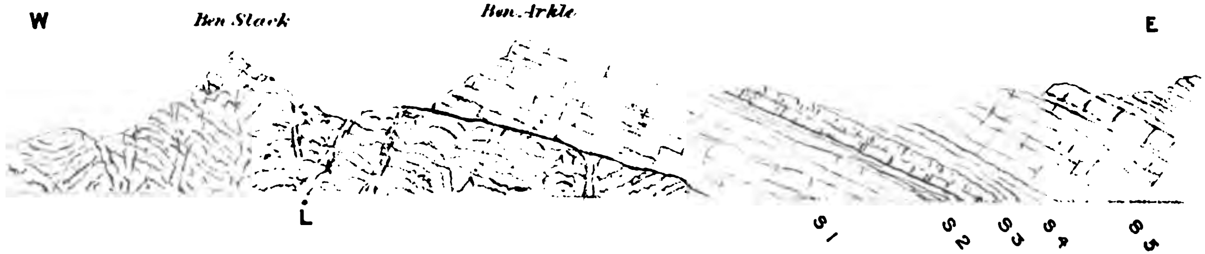
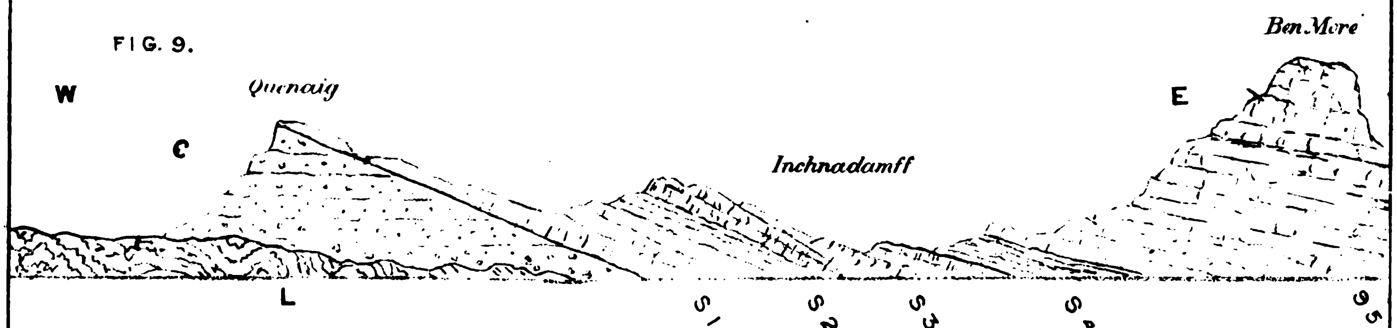

W
Ben Stack
Ben Arkle
E
L
S 1
S 2
S 3
S 4
S 5

FIG. 9.


Ben More
W
Quenaig
E
C
Inchnadamff
L
S 1
S 2
S 3
S 4
S 5

VII.—ON THE IDENTIFICATION OF CERTAIN LOCALITIES MENTIONED IN MY PAPER ON THE DIAMONDS OF INDIA, BY V. BALL, M.A., F.G.S.

[Read, February 21st, 1881.]

SINCE my return to India I have been enabled by having access to several books and maps to fix the position of some of the oldest diamond mines whose identification has been a puzzle to previous writers. I shall not give all the details here, but since this Society was the medium by which my paper (*vide supra*, p. 10), was published, I think it right that I should hasten to make what *amende* I can for having given currency, on the authority of other writers, to views which I am now compelled to withdraw.

RAOLCONDA.

This locality has been a great puzzle to most writers in consequence of their trying to identify it by means of Tavernier's statement that it was five days journey from Golconda, and eight or nine from Visapour (the modern Bijapour). Elsewhere, however, he gives a list of the stages—nine in all—between it and Golconda, the sum of the distances being, I compute, equal to 189 miles. I am, therefore, compelled to believe that in Tavernier's first statement the days' journeys were transposed, and that it should be read eight or nine from Golconda, and five from Visapour. With these new indices of position we at once find a town on the map bearing the name Rawduconda, in Lat. 15° 41′, and Long. 76° 50′.

Unfortunately the geology of this locality is not at present known, but metamorphic rocks have been observed to occur at no great distances both to the north and south of it. It is possible that there may be an outlier of the Karnul rocks there. I have not yet succeeded in finding any recent account of diamonds being known to occur there.

GANI OR COULOUR.

This locality, regarding which I have given a quotation from Tavernier, was almost certainly identical with Purtial, in Lat. 16° 39′, Long. 80° 27′, although Capt. Burton located it on the Bhima river. According to Tavernier, whose stages can to

some extent be identified, it was seven days' journey (about 150 miles) east of Golconda.

At it was found the famous Great Moghul diamond, which by some is considered to have been the Koh-i-noor; it then weighed 900 carats.

SOUMELPOUR, NOT IDENTICAL WITH SAMBALPUR, ON THE MAHANADI.

The Soumelpour of Tavernier on the Gouel river, has been identified by most writers (Karl Ritter being perhaps the only exception), with the modern Sambalpur, and I regret to say that when writing my paper I did not give Tavernier sufficient credit for geographical knowledge, and in spite of his saying that the washings were in the Gouel river which flowed northwards to the Ganges, I followed suit in locating Soumelpour on the Mahanadi river.

There can be no doubt, however, that the Gouel river was the Koel, and that Soumelpour was situated in the district of Palamow somewhere, not very far from Lat. 23° 53′ 30″, Long. 84° 33′.

BEIRAGURH IDENTICAL WITH WEIRAGURH.

I mentioned in my paper a locality—Beiragurh—as having been alluded to by early historians as the site of a diamond mine, and I quoted several suggestions as to its identity. I now find that it is the same place as the modern Weiragurh in Lat. 20° 26′, Long. 79° 31′ 30″, and which I have described in my paper on page 576.

I hope to publish the details of the above identifications in the Journal of the Asiatic Society of Bengal, where they will have the advantage of local criticism. The above sketch of the results will probably be deemed sufficient as a correction of and addition to my former paper read before this Society.

Calcutta, 8th Dec., 1880.

VIII.—ANNIVERSARY ADDRESS TO THE ROYAL GEOLOGICAL SOCIETY OF IRELAND, BY G. H. KINAHAN, M.R.I.A. PRESIDENT.

[Read, February 21st, 1881.]

Before proceeding with the special subject to which I wish to call your attention at this, our Anniversary Meeting, I have to record the departure from amongst us of two Ex-Presidents of our Society.

Charles William Hamilton, M.R.I.A., F.G.S., died on February 16, 1880, the very day of our last annual meeting, at an advanced age. He was one of the original members of our Society, and sometime Secretary, and also President thereof in 1845 and 1846. He was an energetic and well-known field-worker in our Science, at a time when there was no published Geological Map of Ireland to assist the explorer, and has contributed numerous papers to our "Journal." He took an active part in discussions respecting certain formations whose relations were of necessity imperfectly understood, before the extensive induction of facts, which we now owe to the Geological Survey had been made. If he was, as we must believe, unquestionably mistaken as to the age of the rocks forming the mountains between MacGillicuddy's Reeks and Kenmare, we must remember that Sir Richard Griffith and Mr. Jukes, who both disagreed with him, likewise disagreed with each other on the same point; and the question cannot be said to be definitively settled even yet. On the other hand, we must not forget to mention that it was Mr. Hamilton who first pointed out to Sir Richard Griffith, in 1836 (see Phil. Mag., Dec. 1839, p. 444), that the roofing slates at Ringabella Bay, south-eastward of the city of Cork, were really newer than the Old Red Sandstone strata to the north of them. These, from their very ancient appearance combined with the concealment of their junctions with the O. R. S., had been regarded by several eminent geologists as belonging to the "Older Transition" formation, or in modern language as being either Lower Silurian or Cambrian. Mr. Hamilton's bold innova-

tion was afterwards amply confirmed by the discovery in that rock-group of Carboniferous fossils. Mr. Hamilton has set an example which I could wish to see more often followed by geologists in displaying concern for the antiquarian remains of Ireland. During the investigation of the cairns on the Lough Crew hills, in 1865, Mr. Hamilton rendered great assistance, not only by the supply of workmen, but also by personal inspection, and in consequence the marked thanks of the Royal Irish Academy were returned to him for his valuable services on the occasion.

It is with the deepest feeling of regret that we have to record an event which, however, must have taken place before long in the ordinary course of nature, and that is the death, on January 17, 1881, at the ripe age of 82 years, of the venerated Humphrey Lloyd, D.D., D.C.L. (Oxon.), LL.D. (Cantab.), F.R.S., Provost of Trinity College, Dublin. This is a feeling in which all present will share, not only as those who can prize high moral worth and intellectual capacity, but also as Irishmen who can be proud of a distinguished fellow-countryman, and also as members respectively of the two associated Societies of which this is a joint meeting. Dr. Lloyd had been President of the Royal Geological Society of Ireland in 1863 and 1864, and at his death was still Vice-President thereof and of the Royal Dublin Society. He was an original member of the Geological Society, which was established in 1831; his father, Dr. Bartholomew Lloyd, was our first President and as such gave the opening address to the Society in February, 1832. Our late distinguished Ex-President did not make geology a special subject of his attention, although taking a great interest therein; nevertheless the three lines of physical research which he more particularly prosecuted bear more or less strongly on our science.

The first we shall mention is that of Optics. He has left two important works on that subject, viz., A Treatise on Light and Vision, 1831, and lectures on the Wave Theory of Light, besides various papers in the Transactions of the Royal Irish Academy and elsewhere. He it was who was selected to draw up the "Report on the Progress and Present state of Physical Optics" for the British Association in 1834. Physical Optics bears directly on the subject of Crystallography, which belongs to Mineralogy, which, in its turn, is really part of the comprehensive science of Geology; and therefore we find most appropriately inserted in

our Journal a paper, or lecture, communicated to the Society in 1836 by Dr. Lloyd, "On the Optical Properties of Crystals and their relation to the Crystalline Forms." In connection with this we cannot refrain from mentioning now, though it has been so often referred to in various books and papers, the delicate and successful investigation by which Dr. Lloyd verified the prediction of Sir William Rowan Hamilton respecting Conical Refraction in biaxial double-refracting crystals. Sir William, from his discussion of Fresnel's theory, perceived that when a ray of light has traversed a biaxial crystal in the direction of either of the lines of *single ray-velocity* (which lines nearly coincide with the optic axes of the crystal) the linear ray, on emergence, becomes refracted into a cone of rays; this he called external conical refraction. He perceived also that there must be another case of this phenomenon viz., internal conical refraction, which must take place when a ray falls on the crystal so that one of the refracted rays would, according to the usual law, coincide with an optic axis; this ray on entering the crystal must be refracted into a cone, which on emergence would become a cylinder. Dr. Lloyd, seeing that arragonite would be specially suitable for the purpose on account of the comparatively large angle between its optic axes, selected that mineral for experiment and satisfactorily proved the correctness of both anticipations of Sir W. Hamilton, thereby contributing to a very remarkable triumph of mathematical investigation and corroboration of the undulatory theory of light.

Another physical subject which was a speciality of Dr. Lloyd's was that of Magnetism. He was an early and prominent investigator of the phenomena and laws of terrestrial magnetism, and it was through his influence that the Magnetical Observatory at Trinity College was established in 1838. He was largely instrumental in prevailing upon the Government in the same year to send an expedition to the Southern hemisphere for magnetic research; and he and General Sabine were deputed by the Royal Society to go to the continent of Europe to organize magnetical observation there. On this subject he has written "An Account of the Magnetical Observatory at Trinity College, Dublin," 1842, "Dublin Magnetical and Meteorological Observations," 2 vols. 4to., 1865–9, "A Treatise on Magnetism General and Terrestrial," 1874, and numerous papers on the subject in the Transactions and

Proceedings of the Royal Irish Academy, the Reports of the British Association, and various scientific periodicals. The terms "terrestrial magnetism" and "earth currents" at once suggest the reason why geologists are interested in his labours in that line. The part played by magnetism as a geological agent is still very imperfectly understood, but we have already some intimations of it; this form of energy is mentioned by Dana among the causes of events in the earth's geological progress, and as one the laws of which the geologist cannot know too well. Judging from experience we cannot doubt that increased knowledge will, in the course of time, render the magnetical researches of Dr. Lloyd available for the elucidation of various geological problems in a way and to an extent that we cannot now divine.

A third subject which largely occupied the thoughts and time of Dr. Lloyd was that of Meteorology, which is perhaps still more closely connected with geology than either of his two other pursuits. Dr. Lloyd was one of the first scientific men who perceived the importance of ocean currents as heat carriers and effective agents in modifying climates, and was a firm believer in the view first put forward by Sir John Herschel that, in order to account for changes in geological climates, it would be found necessary to take account of secular changes in sun-heat as well as of local alterations in terrestrial conditions. Dr. Lloyd's masterly discussion of the Meteorological Observations made in Ireland, in 1850–1, by the Royal Irish Academy, marked an epoch of decided advance in the treatment of meteorological data.

In his Presidential Address to the British Association, at its meeting in Dublin, in 1857, Dr. Lloyd did not fail to give to geology its due share of notice. But, as we have seen, independently of the fact of his direct interest in our science he was a powerful and helpful ally thereof. In the two fields of research last mentioned he was dealing with cosmical forces which affect both generally and locally the body of our globe. This is a region of discovery into which geology is being ever more and more compelled to extend her outlook, and she is thankful for all light obtained from thence, not being able to work therein for herself. But we must not forget the reflex action between geology and other lines of investigation of nature, of which we have just had an illustration in the matter of sun-heat, not to mention others

that might be instanced; in respect of this the scientific labours of Dr. Lloyd contribute to vindicate her dignity and her status among those other lines of research by showing that they may be in their turn indebted to her for important and unlooked-for suggestions and indications.

WASTE LANDS OF IRELAND.

The subject which I propose now to consider may perhaps be regarded by some as not of a sufficiently geological character to be suitable to the present occasion; yet when we consider that it relates to the practical application of geology to a matter of vital importance to the country, and that I am not only addressing the members of the Royal Geological Society of Ireland, but also those of the Royal Dublin Society, a society one of whose principal objects is the development of the resources of the country, the subject of the cultivation of the Waste Lands of Ireland may not appear to be so much out of place.

The connexion between geological phenomena and agricultural interests is illustrated by the fact that the boundaries of better and worse land, on Griffith's Map of the Soils of Ireland, agree very nearly as a general rule with the boundaries of the different petrological groups. It was in consequence of this connexion that the small edition of Griffith's Geological Map of Ireland was issued to accompany the instructions to the land valuators, and to assist them in their work. There are, however, important exceptions to the just mentioned agreement between the boundaries of lands of different qualities and different rock formations; these, however, illustrate in their own way the same general principle; as, for instance, where "limestone gravel" has been carried by geological agencies on to granite districts, producing there what would be taken for a limestone soil; or where shale or schist gravels and clays have been carried over sandstone areas; or where sandstone detritus has moved on to limestone areas, producing a soil inferior to that which would be derived from the local rock formation.

I wish to point out on the present occasion, as briefly as possible, how a knowledge of nature's laws, as far as they come within the cognizance of Geological Science, combined with the experience

and skill of engineers and agriculturists, may be utilized in improving the unproductive or waste lands of the country.

These unproductive lands may be generally classed as *Flooded Lands* either by the sea, lakes, rivers, or streams; *Lowland*, or *Red Bogs; Mountain Bogs*; *Mountainous tracts; Upland Wastes*, and *Blown Sands*.

A saying of the great Nimmo, often repeated in the west of Ireland, was—"Give me money and men, and I will make a road across Dingle Bay." Whether it be true or not that nearly everything is possible to the engineer, in the matter of the intaking of land we have very seldom to consider the possibility or impossibility of the work to be done, but only by what means it can be carried out at the least expense, so as to be at the same time perfectly effective and profitable; and it is here that the geologist can help the engineer.

As to the reclamation of lands flooded by the sea—the kind of sea-wall that would be likely to suggest itself, on first thoughts, is a structure, which from its simple massiveness would be able to resist the advance of the sea by main force and keep it back. But such a barrier would be necessarily very costly, and we find, after a study of the subject, that a judiciously planned and cheaper defence may be far better. First, then, as to the construction of the wall itself; as I pointed out in a paper read before the Institution of Civil Engineers of Ireland, steep rocky shores present conditions which are favourable for the waves dashing up to greater or less heights; while sands, shingles, and the like, absorb, as it were, and destroy the force of waves; more especially when a beach slopes at different angles. This subject has received considerable attention from the Dutch engineers, who now make their embankments after the best natural form, that is of slopes and flats (cesses) combined. Thus they are enabled to break the force of any wave. They have also learned that nearly any materials will do for the body of the bank (they generally use the sand from outside the embankment), as its stability depends principally on its faces; these they make staunch, not by heavy stone work (except under peculiar circumstances) but with clay, wood, fascines, and the like, as the face of the bank is generally only for a temporary purpose, that is, to preserve the structure while a strand is being banked up against it by tidal or other

currents; and if a strand does not collect outside, they force it to do so by the judicious erection of groynes.

Full details respecting these banks will be found in the writings of the Dutch engineers.

Now, as to the assistance which the geologist can give in the matter of laying out sea-banks. The travelling of sea-beaches and the denudation of coast-lines and other related natural operations are phenomena which come within the range of observation of the geologist, and which he is specially drawn to study, as they bear so strongly on various questions of physical geology with which he is concerned. The knowledge of such operations of nature is indispensable for the proper laying out of embankments and for the arrangement and effective placing of groynes. The latter are most important defences against the sea, not only in protecting embankments, but also for the preservation of the coast in those places where the sea is encroaching and slowly destroying good land. Many of the Irish intakes which have been successful in keeping out the sea, are not as profitable commercially as they would have been if so much money had not been unnecessarily sunk in making the embankment and if groynes had been judiciously employed.

The catchment drains and canals of many of the Irish intakes are defectively planned for want of the study of the nature of floods in rivers and streams. The laws of floods teach us that ordinary floods occur nearly every year, extraordinary ones at intervals of about twenty years, while some of very excessive violence may occur at greater intervals. In disregard of these facts the catchment drains and their appurtenances are usually only calculated to meet the requirements of ordinary floods; and extraordinary floods when they come are always more or less disastrous to the undertaking. To meet the requirements of extraordinary floods, and to give them a sufficient waterway, it is expedient that the banks of the drains should be at some distance from them, and that the bridges be sufficiently capacious.

A knowledge of chemico-geology is necessary to bring the intaken lands into cultivation; this, however, is a subject of such vast extent that it cannot be considered now.

To cultivate lands flooded by lakes it is necessary to drain the lakes more or less. If a lake is only partially drained, the form,

position, and size of the embankments must be determined by a knowledge of the action of wind-waves; and in all cases the catchment drains should be made to meet the requirements of *extraordinary floods.*

For the improvement of *corcasses* and *callows*, that is the low flooded lands adjoining estuaries and rivers, the size, form, and position of the embankments should depend on the nature of the floods to which the estuaries or rivers are liable; making careful provision for extraordinary floods. This point is often neglected, the banks being made as close as possible to the margins of the estuaries or rivers, thus leaving no room for the waters of excessive floods.

Formerly flooding with "dirty floods," or what is called in the valley of the Trent and other places in England "warping," was extensively practised in Ireland to enrich the callows and raise their levels. This has been discontinued in many places; but it might be profitably resumed in the cases of both upland and tidal rivers. In the county Tipperary, adjoining the Little Brosna, I changed altogether the nature of some callow land by cutting off from it the "Black flood" (boggy water) and warping it with "Red floods" (muddy water) of the Little Brosna; and the same thing might be done in numerous other cases. Dirty tides might similarly be utilized, if judiciously let on to the corcasses. This was well illustrated about twenty-five years ago when the Lower Shannon broke into the corcasses below the city of Limerick; for although great damage was done at the time, yet the flooding was allowed to have greatly improved the meadows; and the same thing has been found when excessive tides have broken the banks in the estuaries of the Barrow and other rivers.

In many places there are facilities for warping intakes from the sea, lakes, or rivers with muddy or otherwise fertilizing waters. Warping with sewage is an expedient greatly, if not entirely, neglected in Ireland. It has been done, indeed, in a small way, on a few farms, the farmyard and house sewers being discharged over meadows; but it is neglected in connexion with towns. Dublin, Belfast, Cork, Limerick, and other towns are most favourably situated for changing tracts of slob-land and sands into rich and fertile meadows, if only their sewage was utilized, instead of being turned into the sea to drive away or kill the fish.

We now pass to the Bogs. Of these, those most capable of quick improvement are the flat or flattish bogs in the mountain valleys, and next to them the great Lowland or Red bogs;* these require different treatment, as their nature is, in some respects, dissimilar. The former are usually more or less firm; while the latter have nearly always a soft upper stratum, often over six feet in depth. These differences are due to their mode of growth; the red bogs accumulating almost entirely by organic growth and decay; while during the growth of the flat bogs in mountain valleys foreign peaty matter is drifted on to their surfaces, by wind, rain, runlets, and the like.

Ordinary vegetable soil is due to the growth and decay of vegetable matter mixed with a nearly equal or a greater quantity of mineral substance; the latter being brought up from below by earthworms and other burrowing animals, in addition to what is carried on to the surface by wind, rain, and runlets, or by being deposited from the atmosphere. But bog is a peculiar variety of vegetable soil, as it is formed from excessive vegetable growth and decay, due to superabundant moisture, and has in it little or no admixture of foreign substances; it is more or less like a sponge saturated and swelled up with water. Therefore to improve bog it is necessary to ged rid of the water, destroy its sponge-like character, and add to the upper portion as much mineral matter as will bring it more or less near to an ordinary soil; all of which must be done gradually.

The mountain-valley flat bogs, being of tolerable consistency, are usually easy of cultivation. Small holders of land ordinarily mark off a patch of a size that they can "come at" or bring into cultivation in the period of three or four years. This is fenced round in the autumn or winter by a ditch, which "saps" or "soaks" the bog, and in the spring a portion is laid out in beds and planted with potatoes. With the potatoes, lime, if procurable, and farmyard manure are best; but where seaweed is plentiful it is much used, or "shell sand." Twenty-five years ago the latter was a very favourite manure for "taking in" bog; and large fleets of boats were employed in dredging the sand in

* The "red bogs" are very variable in character, some being much worse than others. In contradistinction to the typical "red bog," pastural portions are commonly called in Ireland *Baun* (anglice, *white*).

the Cork and Kerry bays; the sand was carted inland for miles, even across the mountains into the county Limerick. If the first crop is to be turnips, seaweed is an excellent manure.

It is not an uncommon practice in some places, to cut turf in the furrows after the potatoes are planted; thus additionally draining the peat and deepening the soil. When possible, some carry clay or the like to earth the potatoes; an excellent plan, as it adds to the fertility of the peat. The beds or ridges are laid out of such a width that in three years the whole of the plot has been successively in furrows; thus all the surface of the bog, for a depth of eighteen inches or more, has been disturbed and deprived of its spongy character. The potato crops of the second and third years are usually better than that of the first.

Large cultivators seem now to approve of liming, or, as it is called, "boiling the bog," as it gives the quickest return; but to make permanent grass land of a bog it must be continually top-dressed with gravel, clay, marl, pounded up limestone, or some substance that will add weight; otherwise it will crack in the heat of the summer, then form "tussocks" and eventually revert to bog land. Pounded or crushed limestone, or half burnt lime, which is used by some, is more advantageous than quick lime, because although the latter gives quick return, the others last longer in the soil. Such bogs, if to be cultivated, or "taken in" on a large scale, would require a regular system of drainage; while the spongy nature of the whole tract could be destroyed in one or two years by using a grubber; the plough would be used in place of spade labour.

In the fens of Cambridgeshire there is, in places, good deep corn land over bog from fifteen to twenty feet deep, which has been brought into its present condition principally by the addition of pounded chalk and chalk gravel, and by warping. In many places, as in the counties of Tipperary and Clare, warping might be advantageously employed in the improvement of this kind of bog, by turning on to them, during floods, the thick muddy streams from the hills and uplands; even the streams that only bring down gravel and sand would be beneficial, as proved in many mountain valleys, where a natural warping goes on; such materials carried down by a torrent changing the surface of a bog into pasture. I have noted a remarkable instance of this in the mountains near

Killaloe. A heavy rainfall of one winter, having taken possession of a cart track and cut it over five feet deep, carried the debris, slaty shingle, down and spread it over the surface of a flat bog, thus quite changing its nature. In places, in the county of Wicklow, the farmers warp on a small scale by turning the torrents loaded with granitic sand onto the boggy slopes.

The lowland or red bogs would not be as easily brought into cultivation, especially the soft ones (monegay or flow bogs); because to get rid of the water, deep and extensive drainage is necessary. Some of the extensive improvers and cultivators in Ireland are of opinion that the reclamation of these would be unprofitable. Yet what said William the Third's Dutch settlers? "Give us our own law of empoldering and we will reclaim the Bog of Allen;" and what they could do, we should be able to do. Furthermore, the surfaces of deep bogs have been made good and sound land, on a considerable scale, in England and in Holland, and, on a small scale, in the "bog gardens" on most of the Irish bogs. The Cambridge bogs, as already mentioned, were improved by adding limy matter and warping; the Dutch have largely employed the latter; while for the portions of the Irish bogs which have been changed into good tillage land, "corn gravel" (clayey limestone gravel), marl, and road stuff (pounded limestone), have been used. In a few places that I have noted, warping seems to have been carried on in former years; but I am not aware of any place at which it is practised at present. Around, and even within, the different red bogs there are plenty of materials to improve them. These are the limestone gravels in the eskers, and the gravelly clays in the mounds of Boulder-clay-drift; while in many cases they might be warped from the numerous rivers and streams.

The improvement and bringing into successful cultivation of all the Red, or Lowland Bogs, would be a vast undertaking; yet I am convinced most of them could be made good land at a cost that would eventually prove the speculation a good one; but more especially if the improvement of the surface was combined with the manufacture of the peat into an economical fuel, that is a fuel of small bulk and having its heating properties concentrated; this, however, is a subject that could not be fully treated here; but to bring into proper cultivation the surface of the Red

Bogs would be of incalculable benefit, as it would increase the area of arable land by at least an eighth; and the statesman who carried it to a successful issue would be a real benefactor to Ireland.

The improvement of the mountain wastes is perhaps a more immediately pressing question; because, although eventually they might not be as profitable as either the intakes or the cultivated bogs, yet it could be done more quickly to meet the present hunger for land. It is essentially a geological question, and one that ought to be approached with caution, as former experience has proved that certain lands of this class, will scarcely, if ever, give a return for money expended on them. As is the case with cultivable lands, the quality of mountainous and upland wastes depends in a great measure on the nature of the underlying rocks.

Of the mountain wastes we shall first mention the bogs. Those that are on the hill-tops usually are of small value; most of them, however, may be improved for grazing purposes by surface drainage. The bogs in the mountain valleys and low portions have already been mentioned.

Considerable tracts of the drift in some of the mountain valleys are cultivated; but there are, besides, the gravels (eskers) and moraine drift hills, which in some districts, especially in parts of Munster and Connaught, have been left in a state of nature. The esker drift is nearly always capable of profitable culture by subsoiling in the first instance; while what is principally necessary in regard to the moraine drift is the clearing away the numerous blocks of stone, the draining of the hollows, fencing and planting with timber. These lands being so capable of improvement, it is at first sight a matter of surprise that they should be in their present condition; but according to tradition they were originally forest lands, and since the forests were cut down nothing has been done to them. There are large tracts of such lands in the counties Kerry, Galway, Mayo, &c., capable of being made much more valuable than they are at present; but in all these mountain tracts there are areas which it would be more profitable to plant with trees than to till.

Of the soils made up of the debris of the underlying rocks, perhaps the worst is that in quartzite and quartz rock districts. Those areas in which the rocks are solely quartzite or quartz rock

will frequently be perfectly barren. However, not all tracts of quartzite are so, as associated with such rocks will sometimes be found other schists, or the quartzite may not be pure, thus in part counteracting the bad qualities; as a general rule, such lands unless very favourably situated, as near a large town or the like, will scarcely be profitable as tillage land except in patches, but might be made remunerative if planted with trees. An instance of such ground is presented by the Government lands of the Forth Mountains, county Wexford, parts of which would pay as tillage, but the greater proportion is more suited for planting. Land of this class to be either tilled or planted, ought to be subsoiled and cleared of stones, and the low portions or hollows should be drained.

Soil made up solely of granite debris is very cold and poor and is not much improved when mixed with peaty matter; the debris of other rocks, however, when mixed with growan (rotten granite or granitic sand) changes its nature, more particularly if the foreign substance is limy matter, especially if in the condition of marl. The rich lands of Carlow, on the flanks of the Leinster mountains, owe their character, in a great measure to the mixture of granitic and limestone debris. Elsewhere are also found in granitic area patches of good land more or less due to a similar cause; as, for instance, in the Galway granite hills, on, or adjoining, accumulations of limestone drift.

The highly silicious felstones give debris more or less like quartzite and granite; tracts of such rocks are, however, of limited extent. Basic felstones and whinstones, especially the friable varieties of the latter usually weather into good and rich soils Often, however, although the soil may be good it is so thin as to be unsuitable for tillage, and the land must be used for pasture. The accompanying tuffose rocks, also, are often good soil producers. The richness of some portion of the county Limerick is due to the admixture of the debris of these eruptive rocks and limestone; while in some of the mountains, such as Slieve Partry, county Mayo, the detritus from a course of a friable whinstone or tuff forms a strip of good land. When such rocks occur in mountain regions, their debris might be profitably utilized in improving the land in their vicinity.

The soils due to the weathering of most of the highly metamorphosed rocks are in part allied to the granitic soils; but as such rocks are of different compositions and characters, the resulting soils are variable; strips of land over and adjoining calcareous and some argillaceous rocks being good, while the rest may be bad and unprofitable.

Rocks of Cambrian and Cambro-Silurian ages, which are not very silicious or highly metamorphosed, weather to a considerable depth, and in most cases their detritus is capable of being converted into profitable land by subsoiling, drainage, and liming; lime being necessary to dissolve out the iron, so prevalent in such soils; in most cases, however, the iron cannot be got rid of unless the land is drained as well as limed. Subsoiling is especially necessary in those areas where, between the surface and the solid rock, there is a "shingle" or "rubble," through which most of the soluble parts of the manures applied to the surface will drain away; if, however, the shingle is ripped up and mixed with the surface soil, these parts of the manure would remain in the land. Here it may be pointed out that the natural value of land depends not only on the soil, but also on the subsoil. A stiff retentive soil with a clay subsoil would not be of the same value as the same soil with a gravelly subsoil; while a light, friable soil with a gravelly or shingly subsoil would not be of the same value as the same soil over a retentive subsoil. In the first case the subsoil would retain moisture to the injury of the surface; while in the second there would be a natural drainage. In the third case the subsoil would drain off the moisture beneficial to the land; while in the fourth the necessary moisture would be retained. Furthermore, many subsoils contain ingredients that the surface wants; and by a judicious mixture of both, the last would be greatly improved.

Considerable areas of the land coloured on Jukes' Geological Map of Ireland as Lower or Cambro-Silurian are semi-waste and could be increased in value two, three, or four fold. I am acquainted with some such lands, on which about £8 an acre was spent in draining, liming, and tilling, thereby raising its valuation from three shillings to between twenty and twenty-five shillings.

Perhaps some of the lands that might be most profitably improved are those made up of the debris of the *Old Red Sandstone* (Silurian and Carboniferous). These rocks are principally sandstones, with which are associated a greater or less amount of shales, clay-rocks, &c. The debris of the Carboniferous Old Red Sandstone often occurs, not only on the areas of the parent rocks but also on the adjoining low grounds occupied by Carboniferous Limestone and Cambro-Silurian; consequently the extent of ground so covered is often considerably greater than that occupied by the Old Red Sandstone rocks; as in and adjoining the mountain groups of Munster, Leinster, and Connaught. These lands generally are easily improved, the principal expense consisting in clearing them of the numerous blocks of stone with which they are encumbered. The character of these lands from the agricultural point of view is similar to that of those occupied by moraine drifts; and their present uncultivated condition is due to their having been forest land 150 or 200 years ago. Hundreds of acres of these lands occur in Munster and Connaught, especially in Waterford, Cork, Kerry, Clare, Galway, Mayo, Roscommon, and elsewhere.

There are also mountainous wastes on the tracts of *Carboniferous Slate* of the county Cork; these principally require drainage, clearing of stones, and judicious planting with timber to considerably increase their value. While the *Carboniferous Limestone* hills of Clare might be made more profitable if the winter floods in the Turloughs, or flooded hollows, were preserved for summer use; this is practicable in most cases.

On the *Coal-measures* the land is usually cold and bleak, and large wastes occur, as in Cork, Kerry, Limerick, and Clare. Yet draining, planting, and tilling will make even these profitable; as has been proved in isolated places in the different areas. In the Leinster area considerable portions are in a fair state of cultivation, principally on account of the industry of the colliers. Here it has been found that certain shales, raised out of the coal pits, are most beneficial when used as top-dressing; but not all of them, as some kinds poison the land.

There are also the waste lands on the Tertiary rocks of Ulster; these, however, principally occur in areas of whinstone, a rock that has already been mentioned.

Important wastes are the blown sandhills, on different portions of the coast-line. These in a few places, as at Portrane, county Dublin, have been profitably cultivated; but usually they are only utilized as rabbit warrens. If planted with pine, as in South France, they might be made a source of revenue.

IX.—ON THE RECENT REMARKABLE SUBSIDENCES OF THE GROUND IN THE SALT DISTRICTS OF CHESHIRE, BY PROFESSOR EDWARD HULL, LL.D., F.R.S., DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.

[Read, 21st March, 1881.]

THE author referred to the recent remarkable subsidences which had taken place in the neighbourhood of Northwich, in Cheshire, accounts of which had appeared in the newspapers, and the causes of which were little understood. Having become well acquainted with that part of England some years since, when connected with the Geological Survey of Great Britain, he ventured to offer some explanation of these locally alarming occurrences, which he hoped might not prove unacceptable.

The district where the subsidences had occurred is a nearly flat plain, from 100 to 200 feet above the sea level, traversed by the valley of the Weaver and other streams, composed of the formation known as the New Red Marl, and overlaid at the surface by a few feet of Drift sand or clay. The Red Marl formation is the well known depository of beds of rock-salt in the British Isles, owing to which it had once been called "The Saliferous Marl," and it was owing to the dissolving away of the surfaces of the beds of salt-rock by underground waters, in the manner presently to be described, that the subsidences of the ground had taken place.

There was reason to believe that rock-salt underlies nearly the whole plain of Cheshire formed of the New Red Marl, occupying an area of about 500 square miles. The occurrence of the salt beds had been proved at Northwich, Winsford, Dunham, Anderton, Moulton, Middlewich, Wheelock, Roughwood, Lawton, Baddiley, Dirtwich, Audlem, Nantwich, and Combermere Abbey, all in Cheshire; and Mr. Ormerod had some years ago endeavoured to trace the lines of faulting, or dislocation, traversing the country, according to the different levels at which the beds of salt had been proved. (Quart. Jour. Geol. Soc., Vol. IV.)

It is uncertain, however, whether the salt beds always occur in the same stratigraphical position; and the section of the Marston mine, which the author had visited, showed that there are at least two thick beds of rock-salt at Northwich, having a combined thickness of about 180 feet, and at Winsford of 210 feet.

This section was as follows:—

Section passed through by the shaft of the Marston Mines, Northwich.

	thickness.	
1. Boulder Clay, 2. Red Marl with gypsum,	144	feet.
3. First bed of rock-salt,	75 to 84	"
4. Indurated marl,	30	"
5. Second bed of rock-salt,	96	"
6. Marl and shales with bands of salt,	180	"

The section had not penetrated further, but the author believed that the New Red Sandstone would be found at a short depth underneath.

Beds of rock-salt have been proved in other districts where the Red Marl formation occurs, as at Droitwich and Stoke in Worcestershire, Shirleywich in Staffordshire, Rugby in Warwickshire, Middlesborough-on-Tees (under the Lias), Southport and Preesal, near Fleetwood.* The rock-salt worked at Carrickfergus, discovered in 1850, in a boring in search of coal, occurs in three beds, one of which is eighty-eight feet thick, and 572 feet from the surface.

At Northwich the pumping of brine, from which the "white salt" is obtained by evaporation, has been in progress for many years. Mr. Dickenson, in an official report made by order of the Government in 1873†, has shown that in consequence of the salt works there are two kinds of subsidences in progress, namely, those due to the falling in of old mines of salt-rock, and those due to the solution of the salt-rock owing to the pumping of brine. The former class are local and restricted, although one of these at

* Mr. J. Dickenson, Trans. Geol. Soc., Manchester, Vol. XVI. Mr. Dickenson says, that Budworth Mere and Pickmere are evidently on the outcrop of the top bed of salt-rock and Rosthern Mere on that of the bottom bed. But on consulting the maps of the Geological Survey, he will see that owing to a large fault marked on the map these three meres occupy the same position with reference to the strata.

† Report on "Salt Districts (Landslips)," by Joseph Dickenson, Inspector of Mines.

Wilton is about 450 yards in circumference, and there are many of 250 yards near Northwich.*

The subsidences due to the latter cause are widely extended. At Wilton Mill, in the valley of the Weaver, above Northwich, a large mere (or lake) is now in course of formation, and has been observed to widen its banks since 1790. In 1857 the water covered an area of about 1,300 yards in length, and 400 in breadth, and since then there have been several fresh depressions.

The two lakes called Budworth mere and Pick mere, north of Northwich, have visibly extended—and as they lie in the same valley—they will doubtless ultimately coalesce. Hollows are also being formed at Birches Hall near Winsford, Billinge-green, between Sandbach and Northwich, and near Martin Hall. In the neighbourhood of Crewe, Winsford, Middlewich and other places, the ground has been undergoing a process of lowering for many years, and these have culminated in the recent disastrous subsidences at Northwich, which have been graphically described in the public press.

At Northwich the depth at which the brine is found is about 132 feet below the canal level,† and it is kept down by continuous pumping nearly to that depth. This is about the depth of the upper bed of rock salt. When just tapped, the brine usually rushes in with force. The earlier attempts at sinking into the strata containing the brine—especially amongst old workings of salt-rock—were exceedingly hazardous‡; recently the tapping of the brine is more safely effected by the aid of iron cylinders, as described by Mr. Dickenson in his interesting Report.

From what has been stated above, it will be clear that the Northwich subsidences are due to the solution of the surface of the upper bed of rock-salt, owing to the constant pumping of brine, from which the salt of commerce is obtained. Some idea of the extent to which this process is carried may be formed when it is known that upwards of one million tons (of twenty-six cwt.) are annually obtained by evaporation of brine in Cheshire

* The term "wich" is an old Saxon name for a salt spring. It is used in the "Dom boc" or Domesday Book.

† The canal is ninety-six feet above the level of an ordinary spring tide at Runcorn so if all the salt-rock were dissolved away the valley would be submerged deeply.

‡ The processes are described by Mr. Dickenson's Report, p. 22.

alone, while the rock-salt is extracted to a very large extent by mining. In 1879 the quantities produced in Cheshire were as follows:—

Rock-salt, ...	88,853	tons of 26 cwt.
White salt, ...	1,087,214	„ „
	1,177,057	

Of this 1,045,897 tons was sent down the River Weaver from the Northwich district, so that the process of solution and excavation is rapidly going on.*

The process may be briefly described as follows:—

Water from the surface—consisting of a portion of the rainfall and leakage from the River Weaver and other streams—finds its way downwards through the strata of shale, marl, and bands of stone overlying the rock-salt bed, and lodges on the surface, filling old hollows and excavations, and dissolving the solid salt-rock till impregnated to an extent varying from 21 to 25·5 per cent.† There are also salts, and carbonates, varying from 0·6 to 2·5 per cent., and the general analysis shows that the components resemble those contained in sea water. The brine is being pumped as fast as formed; and as the upper surface of the bed of salt is lowered, the ground above necessarily falls with it. In this way the land about Northwich has subsided to the extent of no less than seventy feet within the memory of man; and it is supposed that the top bed of salt is in some places almost entirely dissolved away. The consequence is that roads, canals, railways, and culverts have constantly to be banked up, and are rising higher and higher relatively to houses and other buildings, which subside with the surface, and are often considerably out of the vertical position. Should the process above described proceed till both the beds of rock-salt are consumed, a large tract of country, including the valley of the Weaver, will be submerged beneath the sea.

This brings me briefly to refer to the "meres" or little lakes, which form so peculiar a feature in the landscape of Cheshire. These are distributed over the central plain, and are of various

* Hunt's "Mineral Statistics" for 1879. The total produce of the United Kingdom for the same year was 2,558,363 tons, of which Ireland produced 30,234 tons.

† According to analyses made by Dr. Holland in 1808.

sizes, from Combermere, which is nearly a mile in length, to small ponds, some of which—like that of Crewe Hall—have been artificially extended by embanking. Besides Combermere, there are Rosthernmere, near the northern margin of the Keuper marls, Talton mere—mere lake—Tableymere Pickmere, Rudworthmere, Flaxmere, Oakmere, Oultonmere, Crewe Hall mere, Doddingtonmere, and Ellesmere.* These all (or nearly all) are situated on the New Red Marl formation, which is generally covered by sand, gravel, and boulder clay. No similar group of little lakes is to be found in any part of England beyond the mountainous districts.

As far as I am aware, no full investigation regarding the origin of the Cheshire meres has ever been undertaken. Mr. Ormerod is believed to have originally suggested, that they owe their existence to the melting of the salt-rock. In 1869 I published the following statement:—"There seems to be considerable force in the view, originating, I believe, with Mr. Ormerod, that the meres, or little lakes, of Cheshire may owe their origin to the local subsidence of the ground, consequent on the abstraction of rock-salt, at present or formerly existing under these spots, by dissolving into brine, which is being constantly carried away by drainage at intervals over the whole area of the New Red Marl."† Of the mode in which such lakes may be formed we have evidence in the cases of the subsidences at Northwich, at Martin Hall near Winsford, at Crewe Hall, and at Combermere Abbey. This last instance occurred about the year 1533. Leyland, in his "Itinerary," relates that "part of a hill, with trees upon it, suddenly sank down, and was covered by salt water, of which the Abbot being informed, caused it to be wrought, but the proprietors of the Wiches compounding with him, he left off working." He adds, that this salt pool still continued in his time, but that no care was taken of it.

* Owing to the depth of the Drift over the country about Ellesmere, there is some uncertainty regarding the formation underlying.

† "The Triassic and Permian Rocks of the Central Counties." Mem. Geol. Survey, p. 101. In Mr. Ormerod's valuable paper on the "Salt Field of Cheshire." Quart. Jour. Geol. Soc., Vol. IV., in which he traces the range of the salt beds and the faults by which they are dislocated. The view above stated of the origin of the meres is rather to be inferred than stated.

The process of dissolution of the salt beds by a natural process of filtration, underground flow of waters impregnated with salt, and their discharge in the form of springs, has been going on for a lengthened period, extending back into pre-human times. Such springs are still flowing in some places, notwithstanding the large quantity of brine artifically extracted from the ground by pumping. The flow of the brine springs must have materially affected the relative surface levels, and where, from some cause or another, the dissolution has gone on more rapidly than in the surrounding district, the subsidences would be more rapid, and a hollow would be formed, into which the surface waters would flow and form a lake or mere. In this manner it is probable all these peculiar sheets of water, generally lying in deep hollows, and known as "the Cheshire meres," have been formed; and when once formed, the tendency would be for them to become larger as time went on.

It may therefore be affirmed that the origin of the Cheshire meres and the Northwich subsidences is similar, only that in the one case the process has been a natural one, in the other artificial.

X.—ON THE ORIGIN AND PROBABLE STRUCTURE OF THE DOMITE MOUNTAINS OF CENTRAL FRANCE, BY EDWARD HULL, B.A.

[Read, April 11th, 1881.]

LAST summer, in company with my father Dr. Hull, and Dr. R. Ball, I had the pleasure of examining that remarkable volcanic region which occupies the province of Auvergne, in central France. With Scrope's exhaustive manual in our hands, and aided by his exceedingly accurate maps and faithful descriptions, we had little difficulty in deciphering the physical geography of this somewhat complicated region.

Our explorations, however, were confined to the district of the Puy de Dôme, as our time did not permit us to extend our rambles so far south as the Mont Dore district or into Cantal. This region is composed of a central group of volcanic cones and craters, extending long fingers or "cheires," as they are locally named, of lava out into the plain of fresh-water formations, limestones, marls, and alluvial deposits, which form the basin of the Allier river, one of the principle tributaries of the Loire. This region of volcanoes may be divided roughly into two groups: 1, the *Domite* division, composed of a trachytic form of lava, and pre-eminent alike by their mineralogical character, size, and shape; and 2, the *surrounding volcanic* hills, composed of scoriæ, ashes, and debris, all truncated cones, their sides sloping at the invariable angle of 30°, and nearly always with one side broken down and emitting a stream of basalt, which flows for a variable distance over the surrounding country.

It is extremely probable that, in accordance with a very usual law, these two groups are also divided *chronologically;* the Trachytic or Domite hills being of older formation than the basaltic vents, otherwise it is hard to explain the isolation of the former, their bases swept by flows of basaltic lava from the throats of the surrounding craters, and standing completely isolated in shape as in mineralogical character from their nearest neighbours.

I do not intend to go into the question of the origin of

Domite; this must at any rate be left to *mineralogists*, and even if I were capable of discussing the subject, I should be sorry in any way to deprive them of such an interesting bone of contention; but all I shall attempt to do is to advance what I hope will be considered a reasonable theory of the internal structure and mode of origin of these strange elevations.

Just to mention the older theories—Desmarest considered them to have been originally composed of granite, which was afterwards calcined *in situ* by a volcanic conflagration environing it! This hypothesis requiring, I conceive, for its elaboration the exercise of a somewhat vivid imagination. Others, Von Buch and Humboldt included, thought that they were enormous *bubbles* blown up by subterranean gases and solidifying in that shape—a theory one would suppose considerably more hollow and unstable than it would fain have made the mountains themselves.

Scrope draws attention to the probable viscosity of the mass of Domite when in a molten state, in contradistinction to the comparative fluidity of basaltic lavas; but does not explain, I think, how this viscosity was able to raise mountains some 2,000 or 3,000 feet above the level of the surrounding plain. I proceed to lay before you the following considerations on the subject.

This Trachyte or Domite being composed almost exclusively of felspar, with crystals of augite and mica in small proportion, has a comparatively low specific gravity, which is again much lessened by its very granular and porous character and the contained bubbles of air, so that its specific gravity is as low as 2·50, or even lower; but this will be sufficient for my purpose.* When we come to examine the basalt of which the more recent lava-flows are composed, we find *its* specific gravity to be much greater, namely—3·0 to 3·10. I will take the average figure or 3·0.

* Since writing the above I have taken the actual density of a piece of Domite and its specific gravity is exactly 2·5. This, however, is after it had been thoroughly soaked in water, and all the air which lodges in its pores expelled. How large a quantity of air is contained in this rock may be judged from the fact that on putting this piece into water it appeared to effervesce, the air escaping in such abundance. Scrope states that when a shower of rain falls on these Domite hills a loud hissing noise is produced, which I can well believe, although we were not so fortunate as to witness the phenomenon. This all points to its density while in the molten state, having been very much less than this; but, as I said, this actual density is sufficient for my purpose.

Now, it will generally be conceded, I imagine, that every volcano which aspires to rise to any height above the surrounding level will, as a preliminary measure, throw up a cone of ashes and scoriæ, and this we find to be actually the case both in modern eruptions, and in these extinct but well-preserved craters which form the bulk of the Auvergne range. When these craters are formed the next thing that happens is that the lava will begin to rise up in them, and it would continue to do so till it filled them to the top, if it were not that the lateral pressure of a fluid mass of such high specific gravity becomes too great for walls of such loosely aggregated material to sustain, so that almost invariably one side gives way, and the lava bursting through deluges the surrounding plain. Now, in some of these cones we have a means of estimating the exact height to which the lava rose before the side of the cone prolapsed, for, according to Scrope, in the crater of the Puy de la Vache this lava level is still marked by a projecting ridge of light scoriaceous matter of a reddish yellow colour, rich in specular iron, apparently part of the frothy scum which formed upon the surface of the ebullient lava, and adhered to the side of the vase at the moment of its being emptied. We verified his observation as far as this ridge of slag is concerned, and it certainly had all the appearance of having been formed in the way he suggests.

Now, this line is about 30 or 40 feet below the present ridge of the crater, and allowing twice this amount for denudation we may safely say that the lava rose to within 90 or 100 feet of the edge of the crater before it burst its way through. But it must be remembered that the density of these basaltic lavas was very high, *i.e.* 3·0 or 3·1. If we suppose them to be replaced by a lava like the *Domite*, having so much lower a specific gravity, it will be readily seen that in that case the lava might completely fill the crater before it began to overflow, which it would then do regularly and evenly at every point of the circumference, without any tendency to break down one of the sides of the crater. This viscous semi-solid mass, permeated with gas bubbles, and with a strong tendency to solidification, would then creep slowly down the sides, forming those inverted bowl-shaped mountains which are so peculiar and distinct in form from the ordinary craters.

The annexed diagram is a section of the Puy de Dôme, constructed in accordance with this idea, and it certainly appears to me that the hypothesis is strengthened by the fact, that the mountain rests upon a base of ashes and scoriæ through which the road winds before one commences to make the ascent of the steepest part of the hill, which commences very abruptly.

Section through Puy de Dome.

a. Cap of Domite.
b. Cone of ashes and scoriæ.
c. Much older basalt from Mont Dore district.
d. Granite forming fundamental plateau.

It is quite easy on simple hydrostatical principles, and with the aid of the data which I have given, to verify at any rate the *possibility* of this explanation, and thus to entitle it to hold its own until a more feasible one is proposed, or this shall have been put to the test of experiment. It is a mere question of the difference in hydrostatic pressure between a column of molten lava of a specific gravity of 3·0, and that of one of the same height, but having a density of only 2·5. Now, in one of these cones the bursting pressure was attained when the heavier lava rose to a height of 800 feet in the crater, and was represented by a pressure at the base of the column of 80 atmospheres or 1,200 lbs. on the square inch. (I presume these cones gave way somewhere near the base,

but to calculate the height at which such a cone would *have* to give way would involve more mathematics than I am master of, and it has no immediate bearing on my subject.) If we suppose this same cone to have been filled with the lighter lava, or Domite, the pressure of a column of this lava of the same height would only have been some sixty-six atmospheres, or 1,000 lbs. on the inch square, against 1,200; or in other words, it would have taken a column of the Domite lava 960 feet in height to produce a pressure equal to a column of the Basaltic lava 800 feet high.

So that as a *matter of fact* this Domite lava, supposing it to have been discharged from a crater of a conical form, as from all analogy we have strong reasons for thinking it must have been, could have acted in no other way than that which I have endeavoured to describe, and would thus have produced bowl-shaped masses of the appearance presented in Auvergne.

XI.—NOTES ON THE TERTIARY IRON ORE MEASURES, GLENARIFF VALLEY, COUNTY ANTRIM, BY PHILIP ARGALL.

[Read, April 11th, 1881.]

HAVING been for some time engaged at the Iron Mines of Glenariff, and having paid some attention to the Iron Ore Measures and associated strata, perhaps I may be allowed to lay before the Society some of the notes I have made from time to time, more especially as I am led to believe that the true nature of the iron ore deposits has still to be learned.

As an introduction, it may be allowable to give a short description of the valley and its rocks. Glenariff is the south-west land continuation of Red Bay, probably so called from the Red Sandstone cliffs which form its northern shore.

The glen is perhaps the most beautiful of all those indenting the Co. Antrim. Around, the basaltic-topped chalk cliffs rise to heights, in places, of 800 feet, their continuity and colours being broken and diversified by deep ravines, faults, and landslips, and over them in places streams of water fall, forming picturesque cascades, often perpendicular, of from 50 to 300 feet in height; while in the distance, as a back ground, across the North Channel, is the Mull of Kantire, with its lighthouse, and the Highlands of Scotland.

At its junction with Red Bay the Glenariff Valley is a mile wide, the red Triassic rocks forming the base of the sloping undercliffs, on either side, but these rocks are best seen at the north or Waterfoot side, where they rise to a height of nearly 200 feet. A quarry was opened in these rocks to procure stone for Red Bay pier; the rocks being traversed by an interesting dolerite dyke which throws up numerous shoots and branches. The main dyke bears N. and S.* and dips 85° to the west. The largest shoot bears also N. and S. but dips east at 75°, and would probably unite or drop into the large one at a moderate depth; these dykes at low water can be traced for some distance along the shore, standing up in a wall about four feet above

* This and other bearings are magnetic.

the Trias. The sandstone near the dyke and branches, is much altered and baked, the original structure of the rock being entirely obliterated.

To the N.E., near Cushendall, the Trias rests direct on a massive conglomerate, which is principally made up of granite and quartz fragments (Lower Old Red Sandstone or Silurian). Thus no coal measures occur in this section, nor is it probable they would be found by boring in Glenariff, if the opinion expressed by your late President (Mr. Kinahan), is correct; namely, that this conglomerate is one of the "shore beds" of the Silurian rocks, that further south-west occur in mass in Tyrone and Fermanagh, still it is not improbable that coal measures may exist further southward under the Tertiary and Secondary rocks at Carnlough or Glenarm.

Over the Trias there are thin bands of greensand, principally yellow and greenish sandstones and brownish clays, with more or less calcareous bands. In the upper beds, calcite veins are frequent, and in one place asbestos occurs in the joints close to a considerable fault, which throws down the basalt nearly against the greensand. At the base of the cretaceous rocks is a very thin bed of fine conglomerate made up of rounded pieces of quartz, and fragments of chlorite in a sandy calcareous matrix. The inlying fragments vary in size from that of a pea to that of a hen's egg, and are usually so fixed in the matrix as to break with it. This seems to be the representation of the upper bed of the "Hibernian greensand" of Tate, and from its appearance it is locally called "concrete."

The Lias, which is of considerable thickness near Larne, does not seem to occur in Glenariff, though there is a small exposure of it a little to the east of Garron point.

The overlying white limestone (indurated chalk) has a specific gravity of 2·6, with a semi hackly fracture; the numerous contained flints sometimes occur in layers parallel to the bedding, but are often scattered irregularly through the mass; the bedding planes are seldom well developed but when they are, the rock quarries into large and good building stone. The most conspicuous and numerous fossil is a belemnite, scarcely a large stone can be quarried that does not contain one or more, while they are also frequent in the flint nodules. The purity of the

chalk and its whiteness facilitates its manufacture into whiting and bleaching powder; when burnt it becomes an excellent lime for agricultural purposes.

In places on the white limestone forming the basal bed of the Tertiary, is a thin ferruginous conglomerate made up principally of abraded flints, clay, and gravel; but occasionally we find a stiff brownish clay (which much resembles the pavement hereafter mentioned, page 103), having imbedded pieces of burnt-looking flint and limestone, also occasional pisolites of iron ore; sometimes, however, the dolerite rests direct on the chalk.

The other rocks of the Tertiaries are the dolerites, basalts, and Tuffs; under the latter being included the laterites, iron ore measures, bauxite (silicate of alumina), and such like. The dolerites may be divided into *upper* and *lower*, or those above and below the main iron ore measures.

The dolerites and basalts occur in flows, protrusions, and dykes, while associated with them are partings of laterite, the ferruginous beds of lithomarge, aluminous and pisolitic iron ores, and seams of lignite. The dolerites are more or less crystalline, sometimes being porphyries, having in them well developed crystals of labradorite and augite, occasionally they exhibit columnar and amygdaloidal structures and have peculiar concretionary weathering; both they and the basalts when in bedded masses occupy large areas, while the tuffs are of more or less limited extent.

The flows of dolerite vary from a few feet to thirty or forty in thickness; usually between them are ferruginous accumulations, to which I drew the attention of Mr. Mallet, of the Indian Survey, during a visit to the mine last summer, and he expressed an opinion that the compact varieties were somewhat similar to the laterites that in India occupy large areas, are often 200 feet deep, and contain nodular iron beds twenty to forty feet thick. Here, however, the beds or partings are only from a few inches to about seventy feet, while in general they do not exceed two feet thick. In places these thin laterites graduate into good aluminous iron ore, but in no case have I found the latter assuming the pisolitic structure; although in the iron ore measures similar aluminous ores will occasionally have pisolites scattered through them when immediately under the pisolitic ore.

The laterite between the dolerite flows is generally of a red, or reddish brown, colour and very tough ; it is invariably amygdaloidal, the cells containing zeolites and aragonite. The laterite partings between the lower beds of dolerite are usually softer or more decomposed than those between the upper beds, and very often graduate into thick ochre and bole beds; this is not so common in the upper dolerites, but in every case which has come under my notice the iron ore measures alone excepted, the laterites are very vesicular and contain large quantities of zeolites. I have also frequently observed manganese oxide in the cells.

From the papers and memoirs on the laterites and associated iron ores to which I have had access, it would appear that they are supposed to be accumulations due to the disintegration of trappean rocks during periods of successive volcanic outbursts; for such a theory I do not, however, see sufficient evidence. The thin ferruginous beds of bole between most of the large flows may doubtless be formed from the disintegration of the scoria or surface of the flows; but the materials forming the thick beds such as the iron ore measures, could scarcely have had such an origin. Their thickness, structure, and other characters suggest that possibly they are eruptions of ferruginous mud, ejected at intervals between the basaltic flows by volcanic agencies, or perhaps eruptions of ferruginous dolerites and tuffs which subsequently decomposed *in situ*. The beds of aluminous ore seem to be contemporaneous with the accumulation of the associated beds, and in all probability are a sedimentary deposit, but the pisolitic ores have characters which would appear to refer their origin to some other cause.

The iron ore measures of Antrim vary from ten to seventy feet in thickness: in the Glenariff mines they do not exceed sixty feet; they and the associated rocks give the following section :—

	Feet.
Upper Dolerites, ...	300
Iron Ore Measures, . . .	60
Lower Dolerites, ...	250
Basal Conglomerate, ...	2
White Limestone, . .	70
Feet, .	682

The iron ore measures give as a typical section :—

				Ft.	In.
6. Steatitic Rock,	local name	"Brushing,"	. . .	0	8
5. Steatitic Clay,	"	Holing,	. . 1 inch to	0	3
4. Pisolitic Ore,	"	First Ore,	. . .	1	7
3. Aluminous Ore,	"	Second Ore,	. . .	2	6
2. Ochreous rock,	"	Pavement,	. . .	15	0
1. Lithomarge,	"	Marge,	. . .	40	0
			Feet, .	60	0

The floor of the lithomarge usually is an irregular surface of dolerite, which in places is corroded into deep holes; dolerite is also found in decomposing masses and boulders in the bottom beds of the lithomarge. In some places the decomposed dolerite passes insensibly into the lithomarge, but in general it is darker than the surrounding lithomarge, and being vesicular, presents a marked contrast to it. The bottom beds of the lithomarge are generally of a light lavender colour containing numerous white spots of bauxite, which vary in size from a pin head to that of a pea; the upper beds are brown or blackish. It is a brittle and splintery rock, and flies from the pick like flint, but is never hard enough to resist being easily cut with a knife, occasionally it is altered by a dyke into an extremely tough rock. When exposed to the weather it becomes soft and breaks into cubes, which eventually weather into spheroidal forms. Interstratified with the lithomarge are inliers of aluminous iron ore, usually as beds varying from a few inches to several feet in thickness, but often only as lenticular masses. Sometimes small partings of a silicious lignite are found in this aluminous ore, also lumps and thin seams of lignite, but I have never observed lignite in the associated lithomarge, though it often occurs in the pisolitic ore seam, as will be described hereafter.

There are interesting circumstances in connexion with the lithomarge when it comes in contact with peat water, which may be here mentioned. When peat water passes over an exposure of lithomarge, oxide of manganese frequently accumulates in the cavities and interstices, one irregular fissure was filled with pyrolusite (of 70 per cent. Mn. O.) in places three inches thick, but on an average not more than one inch in depth, the walls came together, and cut out the seam. The manganese would appear to be in solution in the peaty water, and to be deposited by some pro-

perty in the lithomarge. Also the peat water seems to have a solvent action on the dolerite, from whence it probably draws its supply of manganese and iron, as stones taken from the bogs have white envelopes of ⅛ to ¼ inch in depth, in which there is scarcely a trace of iron, while below this crust the dolerite is dark and very little altered. It may also be mentioned that in the mountain bogs lumps of cellular iron ore are found with the cells filled with oxide of manganese. If these solvent and precipitating actions are at all general, which they ought to be, deposits of manganese should be going on in various places in connexion with the trap area.*

The Ochreous rock over the lithomarge is called "pavement" by the miners, as it forms the floor or pavement of the iron ores. In it the levels and tunnels for extracting the ore are usually driven; it is a soft rock and can easily be cut with the pick. The pavement seldom contains bauxite, except where it is traversed by a dyke, near which the spots are large and numerous.

In general on the pavement, the aluminous or second ore occurs, in the upper portions of which are scattered pisolites (peas of the miners) of iron, and resting on this is the "first" or "pisolitic" ore. In the latter the pisolitic structure is always best developed at the top of the bed, it also being the richest portion, containing larger and more numerous pisolites than lower down.

The pisolitic ore varies from twelve to twenty inches in thickness, but occasionally reaches twenty-four or even thirty inches. In colour it varies from red through brown to black, some of the latter coloured pisolites shine like graphite; the red ores always are over the others; generally, however, the seam of pisolitic ore is of one colour throughout its thickness, this in the Glenariff district is usually dark brown or black. It is the matrix or cementing material for the most part that gives the colour to the ore, the pisolites are generally black, though in red ores they sometimes take a red colour, but of a darker shade.

Near the "face" or cliff outcrop of the seam the ores are soft, the pisolites being in a friable mass of peroxide of iron, but as the bed is followed in, it becomes harder and the pisolites are cemented firmly in the matrix; while at twenty to thirty fathoms from the outcrop the ores are usually too hard for pick working

* See Notes added in the Press. No. 2.

and have to be shot or wedged out. The ores also get harder as the roof or perpendicular weight increases; thus under high escarpments good firm ore is found at five or six fathoms from the outcrop. These are important facts, because at present the best ores may be deteriorated by their fineness, which would prevent them being used by themselves in the blast furnace. As the ore from the shallow workings are exhausted and the mines extended into the heart of the mountain, the ore ought to get harder and contain a greater percentage of lumps, thereby enabling it to compete more favourably with the Spanish ores.

In the present workings the matrix is seldom hard enough to hold the pisolites in position and allow them to be broken across they coming out during the breaking of the ore; but if the beds are traversed by a dyke (which penetrates the roof) the adjoining portions are baked into a compact mass, and under these circumstances the pisolites break with the matrix. The pisolites vary in size from a shot to that of a hazel nut, while the quality and richness of the ore can be estimated with great accuracy, by observing the size, quantity, and hardness of the pisolites. The pisolitic ore contains from 40 to 70 per cent. of iron, the following being analysis of average samples of Glenariff ore:—

—	Pisolitic Red Ore.	Pisolitic Black Ore, Magnetic	Pisolitic Black Ore, Magnetic.	Aluminous Ore.	Aluminous Ore.	Pavement.	Pavement.
Iron Peroxide,	62·43	71·64	67·54	28·83	35·93	28·44	27·96
„ Protoxide,	4·75	1·88	trace	2·50	trace	trace	trace
Manganese Protoxide,	0·28	0·27	0·17	trace	0·11	trace	0·18
Alumina,	10·19	4·25	1·75	34·70	36·50	38·14	4·40
Lime,	2·80	0·81	Nil.	Nil.	0·53	Nil.	trace
Magnesia,	0·59	0·61	trace	1·51	1·41	1·10	trace
Silica,	8·40	5·05	10·93	15·40	12·20	15·90	38·70
Sulphur,	Nil.	Nil.	Nil.	trace	Nil.	trace	Nil.
Phosphoric Acid,	Nil.	0·20	Nil.	0·04	Nil.	0·08	0·07
Carbonic „	trace	trace	Nil.	Nil.	Nil.	trace	Nil.
Titanic „	—	8·89	10·80	Nil.	Nil.	trace	6·60
Combined Water,	1·88	—	2·26	9·00	10·23	12·25	11·36
Moisture,	8·48	6·40	5·61	7·80	2·76	4·60	14·78
Loss,	·20	—	0·94	0·22	0·33	—	0·95
	*100·00	†100·00	‡100·00	§100·00	§100·00	§100·43	§100·00

* A. B. Cowen. † Public Analyst, Wolverhampton.
‡ E. W. T. Jones, F.C.S., Wolverhampton.
§ Ditto, ditto.

The thickness of the pisolitic ore seam is by no means regular, a seam of twelve inches may suddenly thicken to twenty-four or

thirty inches due to a cavity or "rise" in the roof (a roll or "gurry" of the miners); also an irregular wavy or undulating structure in the roof may thin and thicken the seam alternately. Small cavities or vugs in the roof are usually filled or lined with beautiful crystals of aragonite, sometimes stained red but usually colourless.

A steatitic clay, like No. 5 in the general section (page 102), is sometimes found separating two beds of pisolitic ore, the upper bed being usually of a red colour; but I have only found this in disturbed areas. Very often the pisolitic ore is found resting unconformably on the pavement, the bole and pavement having evidently been worn away in places before the ore was deposited; also it is not uncommon to find angular and rounded pieces of aluminous ore and pavement in the pisolitic ore seam, thus giving it a brecciated appearance. In approaching a place where the pisolitic structure of the ore is not well developed and where the ore appears to be indurated by some cause, we usually find a great display of acicular crystals of aragonite on the roof with veins and partings in the ore, which sometimes cement it to the roof; hence a display of crystals on the roof is regarded by some as a sign of poverty; similarly as a display of spar crystals in a standing vein indicates poverty of mineral matter in the percolating fluids when the vein was being filled.

Sometimes the pisolitic ore is absent and the second ore rises to the roof; at other times both the ores, thus causing the pavement and the roof to join together; this cutting out of the ores is generally caused by the roof dipping down on the pavement.

The pisolitic ores are more or less magnetic, some being magnetite. In regard to their colours, the red are only slightly or not at all magnetic; while the brown are also, they may graduate into a black true magnetite; the latter contains 8 to 15 per cent. titanic acid, and is very rich in iron. I have frequently found the pisolites of magnetic ore to be polaric, their elongated axis or poles being horizontal in the seam, and apparently conformable with the present magnetic meridian.

Lignite and bauxite are found to occur in connexion with the iron ore measures in various parts of the county Antrim, and usually replace the pisolitic ore seam, though in places the lignite overlaps the iron ore, in which case the lignite is always separated from the ore by a band of bauxite or aluminous clay. A good

lignite bed is, however, seldom found in immediate connexion with the pisolitic ore seam, though it sometimes is separated by a dyke only.

To Mr. P. Gormon, who has bored through most of the lignite and ore deposits of the county Antrim, I am indebted for the following information. In all cases that have come under his observation the lignite aluminous clay and ore deposits are found adjoining each other; often they are separated by dykes, but when these are absent, the clay and lignite usually overlap the iron ore at the junction of the deposits.

At Killymurish, where there was an extensive deposit of lignite, he bored through forty feet of clay under the lignite seam, and on putting down another bore a little to the south of this, on the confines of the Duneny iron ore field, he cut through eighteen inches of pisolitic ore so close to the dyke of separation that the pavement of the ore was wanting. In another portion of this clay field he bored through five feet of aluminous clay, lignite being absent, then three feet of brown clay, containing iron, and underneath struck the iron ore deposit. At Craighill he also found the ore and aluminous clay separated by a dyke. The silica in this clay was in excess, and the lignite absent, except a thin seam at the north-east corner.

According to this authority, at Ballintoy, Limenagh, and Drumnagaster, the clay and pisolitic ore are found under the same roof and conditions; and he thus states:—

"I would here mention that I have usually found the clay and iron ore associated in the same hill or range of hills, and the clay is invariably found to occupy the W. or N.W. portion of the ground. I might also state, a bore hole was put down in the Killymurish Lignite Mines, about eighteen years ago, by a Scotchman called Twist; his journal recorded that after getting through the clay and lithomarge, he passed through nine inches of coal, then nine feet of limestone, then some shale, and afterwards eight feet of limestone. It was a prevalent theory at that time, that the lignite was a true coal, and by boring deeper various seams of true coal might be reached."

This section is very remarkable and unlike anything that has come under my notice; possibly it was in one of the deposits of the iron measures close above the older rocks, such as that at Craig-na-shoke, due north of Moneymore, recorded at page 159 of "Kinahan's Geology of Ireland."

Usually under the lignite, there is a small band of carbonaceous clay, containing fossil wood, and immediately under this, the

altered lithomarge or bauxite; the purest bauxite being on top or nearest the carbonaceous clay, in depth however, it becomes more and more ferruginous, and ultimately, it changes into lithomarge. Small pieces of lignite have been found in the pisolitic ore seam, in the mines near Ballymena, the Mountcashel mines, and rarely in the Glenariff mines, although on the rise of the beds, both towards the north and east at Throstan and Ardeclines, the lignite is found to replace the pisolitic ore, and in such places, the ferruginous pavement of the ore is replaced by aluminous clay or bauxite. The lignite seems nearly invariably to occur at the margins of the basins of iron measures—and if these iron ores are lake deposits, the lignite is the remains of the shore vegetation—and if the main measures, are one great deposit, then, it would seem to be surrounded at its borders or edge by lignite. The accompanying analysis of the lithomarge shows it to be essentially a silicate of iron and alumina. Therefore, as bauxite is a silicate of alumina, the dissolving out of the iron of the bole or lithomarge, would change either of them into a bauxite; hence, it is highly probable, the organic matter from the decaying shore vegetation (now represented by the lignite), dissolved out the iron from the bole and lithomarge.

Intervening between the pisolitic ore (or lignite, where it occurs in the ore seam), and the roof, a steatitic clay and rock called respectively, "holing" and "brushing" usually occur. This steatitic clay, invariably contains numerous pisolites of crystalline aragonite, which are very often partly decomposed into a soft unctuous mass; it seems probable that they were amygdules in cellular basalt, prior to its becoming steatitic; these pisolites of aragonite are not uncommon in the lower dolerite flows. When the iron ore is hard enough for shooting, the steatitic clay is picked out, "holed" (hence the local name), by the miners, causing a vacancy, into which the ore is lifted by the shot, and broken off from the seam.

The steatitic rock over the clay, in places graduates into steatite, and often contains large lumps of white saponite. This rock is from six to eight inches thick, and would come down in large scales or flakes if not propped. Hence, the local name, as usually, these scales are taken down, that is, cleared or "brushed" off the roof. The brushing is evidently an altered or decomposed dolerite, while the clay is even more altered. They exhibit numerous striation marks, and are more or less laminar; the

direction of the striæ, so well marked in the Glenariff mines, would possibly suggest, that the flow of dolerite which formed the roof, came from the N.E.

The dolerite roof over the brushing, is quite firm and hard, and requires very little, if any, timber to support it; it invariably exhibits a concretionary structure (or mammillary appearance), similar to that seen above ground, in some weathered beds of dolerite. Here, as in other districts, some beds weather into spheroidal forms, while others decompose in layers, more or less parallel to the original bedding of the stone. The hard dolerite roof of the iron ore measures usually has, protruding from it, crystals of labradorite, augite, and aragonite, the latter mineral is also found filling joints in the roof.

Across the iron ore measures, are dykes, which often displace them; those in the Glenariff district, have general bearings of N.5.E., are perpendicular, or nearly so, and vary from a few inches to several fathoms in thickness. Often they have a more or less columnar structure, the columns lying nearly horizontal, or at right angles to the walls of the dykes. The horizontal joints, as a rule, are regular, extending from wall to wall; while the perpendicular joints are not as persistent or regular. From dykes in which both systems are developed, good building stone can be procured. These dykes in the Glenariff mines, may be divided into two distinct classes; first, those which stop at the roof, or "*stop dykes*," and second, those which penetrate the roof, or "*through dykes*," the latter invariably displace the ore measures, and bake the pisolitic ore seam; while the "stop dykes," neither displace or bake the ore seam. The dykes that stop at the roof, have a parting of steatitic clay, separating them from it, similar to that on the pisolitic ore. All the dykes have a film of steatitic clay at their walls, while the various joints are coated with carbonate of lime. When approaching a dyke, cracks in the pavement are frequently filled with acicular crystals of aragonite; the pavement being much tougher, and contains numerous spots of bauxite, some of them being as large as an egg. If a dyke is a through one, large crystals of aragonite are common on the roof, the pisolitic ore being also much altered (baked), having in it numerous joints filled with carbonate of lime, and under such circumstances, the ore comes out in blocks, which if broken open, show very little of the pisolitic structure.

The stop dykes usually have a decomposed or soft head, which

may extend for two feet in depth, sometimes however, they are quite firm and hard at the top, and are separated from the roof by a small parting of clay only. In Glenariff mines, we have one dyke which comes up and turns over, or "splashes" against the roof, proving it to be newer. The through dykes vary from six to twelve feet thick, and the stop dykes from two to six feet.

On the surface of the ground some of the through dykes can be traced to their termination, that is to the sheet of dolerite into which they join; the dyke No. 6,* in longitudinal section can be seen to pass through the roof and overlying dolerites until it joins into the uppermost sheet. The pisolitic ore where in contact with this dyke is burnt into a hard mass, in which the pisolites can be distinctly seen, though they cleave across with the stone of ore when broken open. The dyke No. 7, which is in a down throw of three feet to the west, and though much thicker than No. 6, cannot be seen on the surface of the ground, only bakes the ore slightly and probably belongs to the flow which formed the roof or the one immediately above it. To the west of this dyke there is scarcely any pisolitic ore, but immediately to the east of it there is a magnificent seam probably the best in Glenariff.

No. 9 is a "stop dyke" which varies from two inches to two feet thick. It is very irregular in its course, and in places appears to have come up with considerable force, and splashed or turned over against the roof as shown in the section; but other parts of it do not come up to the roof. Usually, however, the stop dykes have a soft or decomposed head, the one shown No. 10 is six feet thick, and in places is decomposed for three feet in depth; to the west of this dyke there is scarcely any pisolitic ore; but immediately to the east of it there are two good seams, separated by a few inches of steatitic clay, the top seam is red and the bottom one dark-brown; about three fathoms to the east of the dyke the top seam is cut out, while the bottom one increases in thickness.

To the following I would draw special attention in the Glenariff district, I have never found the ore of the same quality and quantity on both sides of a dyke, and from what I can learn the same thing occurs in other mines; as a rule a good seam occurs on one side only which is generally on the east side.

* This dyke was shown on a map and longitudinal section of the iron ore measures which is not published with this paper.

To me this appears important as we find a similar phenomenon in standing mineral veins, when the elvans or cross courses appeared to act as a stop to the filling material. Thus in the case of the pisolitic ore seam, it would appear that the dykes which stop at the roof acted as a sort of stop for the material which constitute the ore seam. As previously stated the pisolitic ore is neither baked nor displaced by the majority of dykes which stop at the roof; while nearly invariably it is displaced and indurated by the dykes which penetrate the roof, from which it would appear, that the pisolitic ore was formed prior to the latter, and subsequent to the former. Yet as previously stated, the relation between the iron ore and the lignite, would suggest the accumulation to be lacustrine. But on the other hand, the pisolitic iron seam is not of even thickness, and is often absent over large areas, also it may thicken at one side of a dyke and not at the other; the pisolitic structure being well developed in one place and scarcely discernible in another, and the largest pisolites being always found next the roof decreasing both in size and number as we descend from it, are facts difficult to explain in a lake deposit. As however, none of the eminent authorities who have written on these horizontal seams, have put forward a theory that will satisfactorily account for those peculiarities in their accumulation, it would be presumption in me to do so.

NOTES ADDED IN THE PRESS.

No. 1.

A large plan and section of the Iron Ore Measures was exhibited when this paper was read; also specimens of the various rocks and minerals referred to in the paper, including those showing the division between the first or pisolitic, and the second or aluminous ore, and between the latter and the pavement.

No. 2.

Since writing this paper I found a deposit of manganese accumulating in a mine that had been abandoned for about five years; the water which formed this deposit came through a crack in the roof, from a bog about 200 feet above. The deposit was chiefly found on the sides and floor of the level as a black oozey mass of which the following is an analysis:—

Manganesic Sesqui-Oxide,	56·4
Ferric Oxide,	15·8
Lime,	6·0
Magnesia	1·2
Water,	19·7
	99·1

XII.—"BLACK SAND" IN THE DRIFT NORTH OF GREYSTONES, CO. WICKLOW, BY GERRARD A. KINAHAN.

[Read, May 16th, 1881.]

In November of last year (1880) I learned from Mr. James Price, M. INST. C.E., that a quantity of magnetic iron sand had been exposed on the beach north of Greystones, by the heavy N.E. gales that had occurred during the previous month.

When I visited the place, some time after, I found that, for a distance of several hundred yards along the top of the beach, and just at the base of the cliff, there was a quantity of this black sand; it occurred in long patches several inches deep, in one case over twelve inches; but none of it was detected in the cliff, either as a bed or vein.

On a subsequent visit, after the thaw that followed the heavy frost of January, I found that most of the places where the black sand had been observed were covered by the *debris* that had fallen from the cliff; from some of the masses that remained visible, a sample of about 7½ lbs. weight was taken, and subsequently washed. The beach on this occasion in several places was quite black, owing to a thin layer of the sand, from which another sample of sand was taken. This layer of black sand appeared to be due to the wind (which was blowing strongly from the north along the beach) blowing away the lighter sand, and leaving the heavier materials behind.

After the high tides, with N.E. gales, that occurred early in March, I again visited the place, and found that though most of the cliff *debris* above mentioned had been cleared away, yet that none of the black sand, either on the beach or along the face of the cliff, was to be found.

Samples of the drift were taken from several places at different heights along the cliff and panned; in all very fine black sand, but none of the coarser kind, was found; some of the beds of fine sand appeared to be richest in the black sand.

In places through the gravel thin beds of a black material were

observed; these were not found to be any richer in the black sand than the ordinary sand of the cliff, the black colour being due to manganese.

All the samples taken from the cliff were found, on washing, to contain a large quantity of shell fragments, large flakes of mica, and fragments of quartz. The drift from which these samples were taken consists of an irregularly stratified gravel and fine sand, with patches of a stiff marl appearing through it, and is overlaid by a stiff strong clay. From the very irregular manner in which this drift is stratified, and from the oblique lamination of the beds, it seems probable that during its accumulation there were very varying currents.

In a sample, consisting of about six pounds, of this arenaceous drift, the black sand weighed four grains.

It seems, therefore, that the black sand occurs sparingly, though widely disseminated through this drift, and that its accumulation on the beach is caused by the waves, during certain gales with high tides, washing away the drift cliffs, and sorting the materials according to their specific gravity. It is also very possible that rich layers, or beds, of this sand may occur through the drift, probably towards the base; but none were observed.

When washing, the samples were first passed through sieves which separated them into five degrees of fineness; each of these was washed in a shallow pan, recognizable minerals being picked out during the process, the gold being found in the residue or tailings. These tailings usually had a specific gravity of about 5·0 to 5·2.

The sand yielded about 21·5 per cent. of magnetic material, of specific gravity 4·8, containing magnetite, chromite, and ilmenite.

In the tailings, after the extraction of the specks of gold and magnetic portions, the following minerals were recognised, viz.:— Cassiterite in small grains; red hæmatite, tolerably abundant; brown hæmatite; iron pyrites, rarely unaltered, but there are many small cubes either partly or wholly altered into brown iron; rutile, rare, only a few specks being detected; besides quartz, both rose-coloured and of a light yellow; garnets, very numerous and many-coloured, including various shades of green, yellow, and red. There are also some fragments that appear to be zircons.

In the samples of "black sand" scraped from off the beach, one large scale of gold and five smaller specks were found.

From the sample of 7½ lbs. taken from the foot of the cliff, and washed, thirty-seven specks of gold were obtained; eighteen specks in the finest portion, fifteen in that of the second degree of fineness, and four in that of the third; none being found in the two coarser portions; it, therefore, appears that the gold is all very finely divided.

Gold was found in small quantities in all the specimens of black sand taken from the beach.

Black sands occur at other places along the east coast. In the Museum of the Royal College of Science, Dublin, there is a specimen of magnetic iron sand from Courtown, where, I believe, it occurs between the mouth of the river and the promontory to the south; it also occurs at Ballymoney, north of the last mentioned locality, from which I obtained a specimen with the following description of its occurrence :—

"*Black Sand, Ballymoney Strand, Co. Wexford.*—From a mile to a mile and a half N.N.E. of Ballymoney fishery a thin film of 'black sand' was observed in places lying on the ordinary fine sand of the beach; these patches always occurred in the immediate vicinity of dykes and protrusions of gabbro, and in one place, on the weathered surface of one of the gabbros, the black grains *in situ* were observed as shown in the specimen. The black sand forming the other specimen was skimmed from off the surface of the fine siliceous sand."

The question naturally arises where do these sands come from? Do their constituents occur in the immediate neighbourhood in some mineral vein or channel? or do they occur widely disseminated through the rocks which, by their disintegration, have furnished this drift, and is their occurrence here in such a concentrated form due to local causes?

The occurrence of the sand along such a limited extent of shore suggests that the mother rock is in the immediate vicinity; and from the fact of magnetic iron occurring on the wall of a gabbro dyke, at Ballymoney, it seems not improbable, that the sand at Greystones may be derived from the vicinity of some of the greenstone dykes that occur in the Cambrian rocks, two of which are close at hand; one seen in the railway cutting near Greystones station, the other on the southern slope of Bray Head. But, on the other hand, the associated minerals (quartz, feldspar,

and mica, with very little green grit fragments) point to the mother rock being either a granite or highly metamorphic schist or gneiss, and none of these rocks are known to occur in the immediate neighbourhood. The mother rock may, therefore, be some distance off, and the concentration here of the "black sand" may be due to local circumstances.

The drift in which this sand occurs is, for the most part, very arenaceous, and contains very little argillaceous matter. It appears to have accumulated where there was a prevalence of rapid and varying currents, and may, therefore, be the washings of some previously formed drift, the concentration of the sand being due to the reaction of two or more currents. This question, however, I would leave to more experienced observers to decide.

NOTE ADDED IN THE PRESS.

In analyzing this sand the following method was adopted, viz. :—After the gold specks were picked out several of the concentrated residues were finely pulverized, mixed together, and boiled for some time in strong hydrochloric acid; this was evaporated to dryness (to expel free acid), boiled for some time with water, and filtered. This filtrate, when examined in the usual way, was found to contain lead and copper in very small quantities, iron and alumina in large quantities, chromium, zinc, manganese, lime, and magnesia in small quantities. The portion insoluble in boiling hydrochloric acid was fused with potassic bisulphate ($KHSO_4$), and the fused mass was dissolved in cold water and filtered. This filtrate was boiled so as to precipitate titanic acid, and filtered. That portion of the fusion which was insoluble in cold water was treated with a little dilute hydrochloric acid and boiled and filtered. In this filtrate and in the filtrate from the titanic acid, copper, iron, alumina, chromium, and manganese were found. After treating the fused mass with hydrochloric acid, the insoluble residue was boiled for some time with caustic potash and filtered. From the filtrate tungstic acid was precipitated on acidifying. The residue, after being treated with caustic potash, was fused with potassic cyanide, and from the fused mass a button of tin was extracted.

XIII.—ON THE LAURENTIAN BEDS OF DONEGAL AND OF OTHER PARTS OF IRELAND. By EDWARD HULL, LL.D., F.R.S., &c., Director of the Geological Survey of Ireland.

[Read, November 21, 1881.]

Abstract.

After a perusal of the writings of previous authors, and a personal examination made in the spring of 1881, in company with two of his colleagues of the Geological Survey, Mr. R. G. Symes, F.G.S., and Mr. S. B. Wilkinson, the author had arrived at the following conclusions:—

1st. That the Gneissose Series of Donegal, sometimes called "Donegal granite," is unconformably overlaid by the metamorphosed quartzites, schists, and limestones which Professor Harkness had shown to be the representatives of the Lower Silurian beds of Scotland (*Quart. Journ. Geol. Soc. Lond.*, Vol. XVII., p. 256). This unconformity is especially noticeable in the district of Lough Salt, near Glen.

2nd. That the Gneissose Series is similar in character and identical in position and age with the "Fundamental Gneiss" (Murchison) of parts of Sutherlandshire and Rossshire, and is, therefore, like the latter, presumably of Laurentian age. That the formation is a metamorphosed series of sedimentary beds has been shown by Dr. Haughton and Mr. R. H. Scott.

3rd. That the north-western boundary of the Donegal gneiss is a large fault between the Laurentian gneiss and the metamorphosed Lower Silurian beds, owing to which the older rocks have been elevated, and have been exposed at the surface by denudation.

4th. That the Cambrian formation of Scotland is not represented in Donegal; and that the unconformity above referred to represents a double hiatus, and is of the same character as that which occurs in Sutherlandshire, in the district of Foinaven, and

Ben Arkle, where the Lower Silurian beds rest directly on the Laurentian gneiss.

5th. That Laurentian rocks may be recognised in other parts of Ireland, as in the Slieve Gamph, or Ox Mountains, of Mayo and Sligo; at Belmullet; and in West Galway, north of Galway Bay, where the rocks consist of red gneiss, hornblende rock, and schist, &c., similar to those in Donegal; they may also possibly occur in Co. Tyrone, as suggested by Mr. Kinahan.

XIV.—ANNIVERSARY ADDRESS TO THE ROYAL GEOLOGICAL SOCIETY OF IRELAND. By Rev. Dr. HAUGHTON, F.R.S., &c., President.

[Read, February 20, 1882.]

Fifty years ago, on the 8th February, 1832, the first annual Address from the President was delivered to the Geological Society of Dublin by the Rev. Bartholomew Lloyd, D.D., Provost of Trinity College. To-day I am called upon by your choice to deliver the Presidential Address on the occasion of your fiftieth anniversary. There is, perhaps, a certain fitness in my doing so; for the Geological Society of Dublin, besides directly contributing to the advancement of geological science by its publications, had a much larger indirect influence by the impulse which it gave to the founding of a Chair of Geology in the University of Dublin, and to the initiation of the Geological Survey of Ireland. I have held that Chair for thirty years, and am happy to say that my successor has been appointed in the person of Prof. V. Ball, one of your distinguished secretaries. My predecessors in the Chair were John Phillips and Thomas Oldham, names of which any University may well feel proud.

During the entire life of the Society, Trinity College has been largely mixed up with its best interests; and when in 1848 the Society, owing to want of funds, was unable to continue the expenditure connected with its Museum, Trinity College offered us a hospitable welcome in exchange for the donation of our museum, which has served as the basis of the geological collection of the University, which has now become amply sufficient for the mineralogical and geological teaching purposes of that great institution.

In 1832, the number of members was 168, and in 1882 it is 138.

During the fifty years of our existence, we have produced fifteen volumes of *Proceedings*, containing the Papers thought

worthy of publication by the Council, of which the following Table contains a summary:—

Tabular View of the Progress of Geological Society of Dublin and Royal Geological Society of Ireland.

Volume.	Date.	No. of Years.	Total No. of Papers.	Palæonto logical Papers.
I.	1838	8	38	4
II.	1843	12	5	1
III.	1849	18	45	6
IV.	1851	20	23	2
V.	1853	22	26	1
VI.	1856	25	21	2
VII.	1857	26	25	2
VIII.	1860	29	43	12
IX.	1862	31	14	3
X.	1864	33	18	6
XI.	1867	36	32	11
XII.	1871	40	37	10
XIII.	1873	42	34	7
XIV.	1877	46	41	6
XV.	1880	49	26	2
XVI.	1881	50	11	0
—	—	—	439	75

The striking features of this Table are—

1. The increasing zeal of the Society in publishing as time went on; for six volumes were printed in the first 25 years of our existence, and nine and one-third volumes in the second 25 years.

2. The enormous preponderance of Physical and Stratigraphical Papers as compared with Palæontological Papers; for, of the total number of Papers published in 50 years (439), only 75

relate to Palæontological Geology, or 17 per cent. of the entire. This peculiarity is at once accounted for by the well-known comparative absence of Secondary and Tertiary Strata in Ireland, as contrasted with the abundance of those fossiliferous beds in England.

Fifty years ago, much of the popularity of the Dublin Geological Society was founded upon ignorance of facts; and many persons were attracted by the idea that the new Society would speedily place Ireland upon a footing of industrial equality with England, Scotland, and Wales, by the discovery of coal-beds and metallic mines, which were supposed to lie hidden in the bowels of the earth, awaiting only the "divining rod" of geological science to call them forth into light and golden profit.

The mineral resources of Ireland, however, remained still what they had always been—moderate in quantity and difficult to bring to market.

To-day, whatever attractions the Society offers are purely scientific; and I may here mention two speculative problems which await their solution and must occupy a foremost place in the geological discussions of the next fifty years:—

I. *The absolute duration of Geological Time.*

II. *The Physical Causes of the Changes of Climate which have, beyond question, taken place in the higher Latitudes of the Earth's Surface.*

I. *The absolute duration of Geological Time.*

The first of these difficult problems has been most ably discussed by the Rev. Maxwell H. Close in his Presidential Address, delivered here four years ago (1878), in which he showed that (at least) something might be said by geologists in reply to the arguments in favour of the short duration of geological time alleged by mathematicians, based upon—

(*a*). The time requisite for the cooling down of the Sun.

(*b*). The present figure of the Earth as compared with its present rate of rotation.

(*c*). The estimate of Geological Time derived from the rate of increase of terrestrial temperature with depth.

In support of Mr. Close's reasoning, based upon the latter facts (*c*), I hope at some near date to strengthen his arguments by a new one, founded on the reaction of the outward envelopes of the earth upon its interior, produced by chemical forces, by means of which a slow combustion (ἠρεμοκαῦσις) of the earth takes place, from without inwards, masking the real rate of increase of temperature due to the supposed original heat of the cooling earth; and showing that the introduction of this new element of heat will increase the probable duration of Geological Time.

Since Mr. Close delivered his address, a remarkable addition has been made to what I may fairly call "*Empirical Cosmology*," by Mr. George Darwin, in his Papers on "Tidal Evolution" (see Appendix). Professor Robert Ball,[1] of Trinity College, has proposed to use this speculation of Mr. George Darwin as a means of explaining the great thickness of the stratified rocks, which, as I have shown, if deposited at the present rate of action of geological agents, would require (if the strata were deposited over the whole floor of the ocean) at least 200 millions of years for their formation.[2]

This calculation errs in excess, for two reasons—

1. As Mr. Alfred Russel Wallace has pointed out,[3] I have assumed the sediment to be spread out over the whole floor of the ocean-bed, whereas, in reality, it is and always has been, spread out under water along a comparatively narrow margin of sea bordering the coast lines. Mr. Wallace, accepting my estimate of total thickness of stratified rocks at 177,200 feet, corrects my calculation of the duration of geological time as follows: he assumes the products of denudation to be spread over the coast lines of the continents to a distance of 30 miles from land, on the average; and estimates the coast lines at 100,000 miles, which gives 3,000,000 square miles for the area of deposition. Mr. Wallace estimates the land surface exposed to denudation at 57,000,000 square miles, or 19 times the area of submarine deposition; and assuming the present rate of denudation to be one foot per 3000 years, we

[1] *Glimpse through the Corridors of Time.* Macmillan & Co., 1882.

[2] Haughton, *Lectures on Physical Geography*, p. 95. Sir Charles Lyell, in the 10th edition of his *Principles of Geology*, estimates (from the rate of modification of species of mollusks) 240 million years from the Cambrian to the present period.

[3] *Island Life*, pp. 214–216.

can readily calculate the duration of Geological Time to be about 28,000,000 years.

2. It is highly probable that during all geological time, from the beginning down to the close of the Tertiary period, the temperature of the Earth's atmosphere has been higher than at present, and the more so the farther back we go into Geological Time. The necessary consequence of this would be—greater evaporation, greater rainfall, greater denudation, greater trade and anti-trade winds, greater ocean currents, and greater facilities for spreading and depositing sub-marine strata.

According to Mr. Darwin's speculation, the Moon and Earth have been for much more than 50,000,000 years receding from each other, a process which is known still to continue. Now, the tides produced by the Moon upon the Earth vary inversely as the cubes of the distance of the two bodies; so that when the distance was one-half, the lunar tide would have been 8 times as great as at present; and when the distance was one-sixth, that tide would have been 216 times as great as at present.

Dr. Ball thought that, possibly, these large tides may have continued to act during the deposition of the Eozoic rocks, which form about 18 per cent. of the total thickness of the stratified rocks. Mr. J. S. Newberry, from extensive examination of these rocks in N. America (where they are typically developed), has come to the conclusion that they do not furnish evidence of tides much greater than those now in action on the Atlantic shores of N. America.[4]

Professor Ball has, I believe, subsequently modified his opinion, and now thinks that the great tides caused by the lesser distance of the Moon were pregeological.

II. *Physical Causes of Changes in Geological Climates.*

The general evidence in favour of warmer climates in high latitudes in Geological times need be only summarized here, as I prefer devoting the remainder of my Address to the discussion of their possible causes.

1. Coral reefs abound all through the high latitudes in the

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[4] It must be borne in mind that these include the 70 ft. tide of the Bay of Fundy, which is the largest tide known.

Upper Silurian rocks of the American Arctic islands and mainland; and there is no reason to believe that Palæozoic corals did not require a temperature never below 68° F. in January, which is the climatal condition necessary for the existence of Neozoic reef-building corals. This condition is now never found farther from the equator than 30° lat. This indicates a tropical climate in North America in Silurian times between 70° and 80° N. lat.

2. In the Liassic rocks of the Parry Islands, remains have been found in situ of *Plesiosaurus*, *Teleosaurus* (allied to *Gavial*), *Ammonites*, and other fossils, which indicate climatal conditions of a subtropical character similar to those now found in the delta of the Mississippi and Ganges.

3. The Tertiary fossil plant remains of Grinnel Land indicate a former climate similar to that now possessed by the Gulf of St. Lawrence and the Baltic Sea.

Similar remains in Spitzbergen indicate a former climate like to the present climate of Vancouver's Island.

Similar remains from Disco, on the west coast of Greenland, indicate a former climate like to the present climate of places 30° S. of Disco.

Supposed Causes of Changes in Geological Climates.

I shall briefly consider these, commencing with supposed astronomical causes.

(A). **Supposed former Effects of Star-heat.**—Poisson supposed, in order to account for the increase of underground temperatures with depth, that the earth and entire solar system had, at some remote epoch, passed through a portion of space much warmer than that we now occupy.

The present temperature of space is not many degrees above absolute cold, which is 460° below zero of Fahrenheit's thermometer; and whatever temperature it may have above the absolute cold is due to star-heat. If during Geological periods star-heat had ever been comparable with sun-heat, this fact would be shown by an increase of terrestrial temperature as we descend from the surface into the interior.

(B). **Obliquity of Ecliptic.**—Geologists not acquainted with physical astronomy have speculated on former changes in the

obliquity of the ecliptic which would produce the climates required by the evidence of fossils.

As this speculation postulates the change of position of the earth's axis in space, it must be set aside as irrelevant.

(C). **Changes in Position of Pole.**—A change in the position of the earth's axis within the earth itself, in consequence of which the poles and equator would shift their positions, is possible, and has been often appealed to as an explanation of the changes in Geological climates.

Such a change of position of the axis of rotation inside the earth would be produced by changes in land and water, such as geology gives abundant evidence of.

The question of *how much* change in the pole could be produced in this way has been attempted by Mr. George Darwin and myself.

Mr. G. Darwin takes the area of Pacific depression as estimated from his father's researches on Coral reefs, and determines mathematically the form and position it should have in order to produce the maximum change of position in the poles, and finds the maximum change of latitude to be 3°, or 210 miles.

I took the case of Europasia, which we know has been raised since the commencement of Tertiary times, and calculated, mathematically, the change of latitude which was caused by the elevation of that continent, and found it to amount to only 1° or 70 miles.

How inadequate these changes of latitude are to account for the geological facts recorded by the fossils will appear from the following list of latitude changes required by the geological evidence :—

Evidence of Change of Latitudes.[5]

Silurian Corals, . .	50° . .	3640 miles
Liassic Fossils, . . .	43° . .	3010 „
Grinnel Land Plants, .	36° . .	2520 „
Disco Plants, . . .	30° . .	2100 „

(D). **Eccentricity and Perihelion Longitude of the Earth's Orbit.**—Another astronomical cause of change in Geo-

[5] It is worth while to add, that even if the mathematicians were to allow the geologists to shift the Poles as much as they wished, the geologists would be unable to state where they would propose to place the Poles so as to account for all the climates of all lands.

logical climate was proposed by Adhemar, and afterwards worked out more fully by Croll, J. J. Murphy, and Wallace.

This is the secular variation in climate depending on the eccentricity and perihelion longitude of the earth's orbit.

The change depending on the position of the perihelion is completed in about 21,000 years; while that depending on the eccentricity requires much more time to pass through its course. In fact, astronomers have proved that the eccentricity of the earth's orbit may have been $\frac{1}{12}$th instead of $\frac{1}{60}$th, as at present; but are unable to say how long ago the maximum eccentricity occurred.

Adhemar, Croll, and Murphy deduce from this astronomical cause the alternate glaciation of the northern and southern hemispheres every 21,000 years, which glaciation is more or less severe in proportion as the eccentricity during the perihelion period is greater or less. Mr. Croll, however, places the glaciation of a hemisphere in the time when its winter solstice is in aphelion; whereas Mr. Murphy places the glaciation of a hemisphere in the time when its winter solstice is in perihelion.

I have given a mathematical demonstration of the form of this secular inequality in climate,[6] which may be thus expressed without the use of mathematical symbols:—

The mean annual temperature of any place varies as the eccentricity of the earth's orbit, and as the range of temperature from summer to winter jointly.[7]

Of these two factors of climate, viz., eccentricity and range of temperature, the first is astronomical and the second terrestrial, depending on distribution of land and water, on ocean currents and prevailing winds.

If we suppose the terrestrial factor to be the same, while the eccentricity attains its maximum, the greatest possible change in mean annual temperature for any place on the earth's surface

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[6] *Proceedings of the Royal Society*, 19th February, 1881.

[7] $$\Theta_0 \propto \epsilon\rho$$

where Θ_0 = mean annual temperature;

ϵ = eccentricity of earth's orbit;

ρ = annual range of temperature at place.

turns out to be less than 5° F.; and in order to produce a sensible effect upon climate, we must suppose that the annual range (terrestrial factor) must vary also by variation in the distribution of land and water. This is of course possible; but such a variation must follow its own development, and be quite independent of eccentricity or perihelion.

I shall allow, however, the advocates of this theory permission to make the terrestrial factor what they please (within the limits which the observed facts of climate permit), and then inquire whether the theory can account for geological climates.

1. I take as my first example the present climate of Discovery Harbour, Grinnell Land, close to the Miocene Plant-beds:—

Discovery Harbour.

July temperature, . . .	+ 37°·2 F.
Mean annual „ . . .	− 1 ·7 „
January „ . . .	− 40 ·6 „
Annual range, .	77°·8 „

I have elsewhere[8] shown that the July temperature of Discovery Harbour, during Miocene times, was probably higher than 63°·7 F.; that is to say, 26°·5 F. higher than its present amount. This would require, at the time of maximum eccentricity, an annual range of temperature greater than 120°·7 F.[9]

The foregoing amounts to a demonstration, that a change in the eccentricity of the earth's orbit from $\frac{1}{60}$th to $\frac{1}{12}$th would not produce in Grinnell Land the summer temperature necessary to ripen its Miocene fruits, unless it were accompanied by such a redistribution of land and water as would raise the annual range of temperature from 77°·8 F. to 120°·7 F.; that is to say, increase the already great range by more than half its present amount.

I have no hesitation in saying that (with the present quantity of sun-heat) this amounts to an impossibility.

[8] *Lectures on Physical Geography*, p. 321.

[9] For $\frac{\epsilon\rho}{2} + \frac{\rho}{2} > 63°·7 + 1°·7 > 65°·4$ F.;

therefore, when $\epsilon = \frac{1}{12}$, ρ must be greater than 120°·7 F.;

if $\epsilon = \frac{1}{60}$, ρ must be greater than 128°·7 F.

The greatest range of annual heat now found in N. America occurs at Melville Island, where we have—

Melville Island.

July temperature, . .	+ 42°·35 F.
January ,, . .	− 36 ·40 ,,
Range, . .	78°·75 ,,

The greatest known annual range of temperature occurs (as we might expect) in the north-eastern part of Europasia. Observations taken at Jakutsk for seventeen years give the following results—

Jakutsk.

July temperature, . .	+ 62°·15 F.
January ,, . .	− 43 ·82 ,,
Range, . .	105°·97 ,,

This shows that even a redistribution of land and water, replacing N. America by a continent like Europasia, would still leave the annual range of temperature 16°·73 F. short of what the Miocene vegetation of Grinnell Land requires. This is a *Reductio ad absurdum* of the changes of Geological climate produced by the secular inequality of the eccentricity and perihelion longitude of the earth's orbit.

Similar arguments may be applied to the other well-known Miocene Plant-beds of the high northern Atlantic latitudes.

2. For a second example, in Miocene times, Spitzbergen must have had a July temperature greater than 64°·4 F.[10] Its present climate is—

Spitzbergen, 78° *N.L.*

July temperature, . . .	+ 37°·2 F.
Annual ,, . . .	+ 16 ·5 ,,
January ,, . . .	− 4 ·2 ,,
Range, . .	41°·4 ,,

It is easy to see that the annual range of temperature in

[10] *Lectures on Physical Geography*, p. 332.

Miocene times in Spitzbergen must have exceeded 88°·4 F.[11] at the time of maximum eccentricity, in order to account for the fruits ripened there in summer.

This, although not an impossible case, like the former case of Grinnell Land, is yet quite incredible; for we have to imagine a redistribution of land and water such as would more than double the annual range of temperature in Spitzbergen, or raise it from 41°·4 F. to 88°·4 F.

3. The Miocene Plant-beds of Disco, on the west coast of Greenland, furnish a third proof that change of eccentricity of the earth's orbit is not sufficient to account for former geological climates. The present climate of Disco is—

Disco.

July temperature,	. . .	+ 44°·1 F.
January ,,	. . .	− 4 ·9 ,,
Annual ,,	. . .	+ 19 ·6 ,,
Range,	. .	49°·0 ,,

The probable Miocene July temperature of Disco was greater than 72°·3 F.[12] From this it follows, that the annual range of temperature at Disco in Miocene times must have exceeded 97°·2 F., when the eccentricity of the earth's orbit was a maximum.[13]

(E). **Geographical Distribution of Land and Water.**— In discussing the effects of change in eccentricity of the earth's orbit upon climate, I showed that it brings in necessarily, as a terrestrial factor, the annual range of temperature, which depends altogether (as is well known) on the geographical distribution of

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[11] For $\frac{\rho}{2}(1+\epsilon) > 64°\cdot4 - 16°\cdot5 > 47°\cdot9$ F.

This gives, when $\epsilon = \frac{1}{12}$, $\rho = 88°\cdot4$ F.

[12] *Lectures on Physical Geography*, p. 340.

[13] For $\frac{\rho}{2}(1+\epsilon) > 72°\cdot3 - 19°\cdot6 > 52°\cdot7$ F.;

$\rho(1+\epsilon) > 105°\cdot4$ F.;

and, when $\epsilon = \frac{1}{12}$, $\rho > 97°\cdot3$ F.

land and water; and I have just shown that, allowing every possible effect to both causes, they are inadequate to account for the past changes in Geological climate. A serious doubt, however, now arises as to what limits physical science must impose upon the speculations of geologists as to the arbitrary transposition, on a large scale, of sea and land.

Physical geology has long taught the practical permanence of the existing ocean beds, which have all the character of depressions in the general level of the earth's surface (similar to the so-called *Mare Crisium* in the moon), formed at the very beginning by the shrinkage of the earth's surface, into which the surface-waters gravitated. Geological changes of level appear to have been confined mainly to elevations and depressions of the existing continents, so extending or diminishing their areas.[14]

A flood of new light, pointing in the same direction, has been thrown upon the subject, from the biological side, by Mr. Alfred R. Wallace, who has arrived at conclusions identical with those of physical geologists, from a profound study of the relations of the Fauna and Flora of oceanic islands with the Fauna and Flora of their nearest continents.[15]

The general tendency of all the evidence bearing on this question is to put limits on speculation as to the existence of continents formerly existing in places now occupied by deep ocean beds.

I may give two examples of the effect of this limitation upon geological speculation:—

1. All migrations of plants and animals between N. America and Europasia, or *vice versâ*, must have taken place *viâ* Behring's Strait, and not by means of an impossible continent connecting Greenland and Europe across the north Atlantic, which has been in existence as a deep sea valley filled with water from the time before life existed up to the present moment.[16]

2. The flora of Kerguelen's Land was obtained from S. America

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[14] This is remarkably true (as shown by Dana) of the continent of N. America.

[15] *Island Life*, pp. 81–102.

[16] I have elsewhere shown that the Gulf Stream was in existence in Miocene times, and had the effect of benefiting the mean annual temperature of Spitzbergen to the extent of 4°·8 F. (*Lectures on Physical Geography*, p. 342.).

by means of an extension of the Antarctic continent, and not by means of an impossible continent bridging the South Atlantic from S. America to S. Africa.

If these views be correct, not only are the relative positions of land and water comparatively fixed, but also the present differences between the northern and southern hemispheres have existed from the beginning, and are due to an eccentric position of the earth's centre of gravity, in virtue of which the southern hemisphere has been, and always will be, more under water than the northern.

Two remarkable consequences follow from this, which have been demonstrated by recent observations, although they are at variance with the received traditions of geological and school books :—

1. The southern hemisphere is warmer than the northern, because it receives three tepid currents of equatorial water instead of one.

2. Continental climates are, and have always been, characteristic of the northern hemisphere; and insular climates characteristic of the southern hemisphere, and always will be.

(F). **Alterations in Sun-heat.**—I have kept for the last what seems to me to be the most probable of all causes of change in Geological climate, whether cold or hot; alterations in the heat radiation of the sun itself. It is an admitted fact that at this present moment the surface of the earth receives from the sun nearly 4000 times as much heat as it receives from the body of the earth.[17] As Sir John Herschel well described it, we are roasting at the "jack of the universe," and dependent altogether for the climates we enjoy on the fuel supplied to the central fire.

That the sun has been cooling is, in my opinion, sufficiently proved by the diminishing temperature of successive Geological periods; and that he is subject to "cold fits" is shown by the sinister facts of the glacial period—into which, at present, I have

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[17] The heat (small as it is) received by the surface of the earth from the interior, is commonly supposed to arise from the formerly great heat of the earth. This is an unproved hypothesis; and the chemical reactions of the substances at the earth's surface are, probably, quite sufficient to account for the small *quota* of terrestrial heat.

no wish to enter, beyond the expression of an opinion that the glacial period or periods were non-periodic; that they affected both hemispheres simultaneously, and depended altogether on physical changes in the sun itself, and not on the physical or astronomical conditions of the earth.

APPENDIX.

Let M, M' denote the masses of the Earth and Moon revolving in circles round their common centre of gravity, and let Ω be their orbital angular velocity; then the Moment of Momentum of their orbital motion is

$$G = M\Omega\left(\frac{M'r}{M+M'}\right)^2 + M'\Omega\left(\frac{Mr}{M+M'}\right)^2,$$

or

$$G = \frac{MM'}{M+M'}r^2\Omega. \qquad (1)$$

But, by the law of periodic times, in a circular orbit,

$$\Omega^2 r^3 = \mu\,(M + M'), \qquad (2)$$

where μ is the attraction between unit masses at the unit of distance.

Substituting in (1) the value of Ω found from (2), we have, after some reductions,

$$G = \frac{\sqrt{\mu}MM'}{\sqrt{M+M'}}\sqrt{r}. \qquad (3)$$

If G' denote the Rotational Moment of Momentum of the Earth and Moon, then

$$G' = I\omega + I'\omega', \qquad (4)$$

where I, I' are the Moments of Inertia of the earth and moon with respect to their axes of rotation; and ω, ω' their angular velocities of rotation at any time.

In former times G' was diminished by the friction caused by the tidal action of the earth upon the moon, and of the moon upon the earth. The former of these has ceased to act; because the moon's rotation has been reduced to equality with her orbital rotation. The moon still acts upon the earth, and causes by tidal friction a retardation of the earth's rotation and increase in the length of the day. If we suppose the earth rigid, and the ocean all collected in an equatorial canal, the alteration in G' produced by tidal friction will be, on the supposition that the friction of the ocean is proportional to the relative velocity,

$$dG' = k \sin 2\phi \times a \times m dt, \tag{5}$$

where

$a =$ radius of earth;

$k = \frac{3}{2}\frac{M'a}{r^3}$;

$r =$ distance of moon from earth;

$m =$ mass of the two water-caps contained between the tidal spheroid and inscribed sphere;

$f =$ coefficient of friction;

$n =$ angular velocity of earth's rotation;

$\phi =$ angle between major axis of tidal spheroid and line joining centres of earth and moon;

$$\tan 2\phi = \frac{f}{2(n - \Omega)}.$$

If we suppose the existing ocean contained in an equatorial canal, whose depth is δ and width w,

$$m = \pi w a (c - a),$$

where c is the semi-axis major of the tidal spheroid.

It is known, from the Dynamical Theory of the Tides, that

$$c - a = \frac{kV_0\delta}{\left(V_0^2 - \frac{k^2}{4(n-\Omega)^2}\right)(n - \Omega)} = \frac{kV_0\delta(n - \Omega)}{V_0^2(n - \Omega)^2 - \frac{k^2}{4}}, \tag{6}$$

where $V_0 = na$, the equatorial velocity of the earth.

Hence, equation (5) becomes

$$dG' \propto \frac{k^2 V_0 (n - \Omega) \sin 2\phi \, dt}{4V_0^2(n - \Omega)^2 - k^2};$$

and, substituting for $\sin 2\phi$, in terms of $\tan 2\phi$, we obtain, finally,

$$dG' \propto \frac{k^2 f V_0 (n - \Omega)\, dt}{(4V_0^2(n-\Omega)^2 - k^2)\sqrt{4(n-\Omega)^2 + f^2}}. \tag{7}$$

By the principle of conservation of areas,

$$G + G' = \text{const.};$$

$$dG + dG' = 0.$$

Therefore, from (3) and (7) we have

$$d(\sqrt{r}) \propto k^2 f \Phi\, dt. \tag{8}$$

where

$$\Phi^* = \frac{V_0(n-\Omega)}{(4V_0^2(n-\Omega)^2 - k^2)\sqrt{4(n-\Omega)^2 + f^2}}.$$

The function Φ varies very slowly during the tidal evolution of the earth-moon system; and since k varies inversely as the cube of the distance of the moon, equation (8) becomes

$$\Phi dt = A' r^{\frac{11}{2}} dr;$$

or, integrating,

$$\Phi t = A' r^{\frac{13}{2}} + B';$$

or

$$t = A r^{\frac{13}{2}} + B, \tag{9}$$

where A and B are coefficients that vary very slowly with the time.

The comparison of Halley's coefficient of the moon's secular increase of mean motion, derived from ancient eclipses, with the correction in Laplace's theoretical coefficient made by Professor Adams, has led Delaunay and other astronomers to believe that a tidal lengthening of the day, amounting to one second in 100,000 years, would reconcile the difference in coefficients; and I showed, at the York Meeting of the British Association (1881), that, with the ocean placed in an equatorial canal 10 miles deep, and of a width 10° lat. at each side of the equator (which is sufficient to contain the whole ocean), a value of $\phi = 5°$ (= 20^m) would be sufficient to account for this amount of retardation, taking both solar and lunar tide into account.

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* It is evident that Φ, if expanded in powers of $(n - \Omega)$, contains none but odd powers, and vanishes when $n = \Omega$. Mr. George Darwin, in his Paper on the *Tidal Friction of a Planet*,* on the supposition that the earth was viscous during the evolution of the earth-moon system, obtains a result remarkably like equation (8). It may be written thus—

$$d(\sqrt{r}) \propto k^2 \Psi dt,$$

where

$$\Psi = \frac{p(n-\Omega)}{1 + p^2(n-\Omega)},$$

where p depends on the viscosity, inversely.

* *Phil. Trans.*, Part ii., 1881, p. 494.

A greater amount of present tidal retardation would throw all the old eclipses "out of gear"; and, indeed, Mr. Simon Newcomb thinks that two-thirds of Delaunay's retardation would be sufficient to reconcile the ancient eclipses with Professor Adams's coefficient.

If the present rate of retardation of the earth's rotation be supposed to extend backwards for 100 million years, the length of the day would then have been 85,400 seconds instead of 86,400 seconds, as at present.

Now, it follows from Mr. George Darwin's Paper on Tidal Evolution,* that the relation between the day and month (moon's periodic time), is

$$T = 2\pi\left(4 - \frac{2\pi}{\tau}\right)^3, \tag{10}$$

where

$$T = \text{month};$$

$$\tau = \text{day};$$

$$\text{Unit of time} = 2^h.41^m.$$

Hence, if T' and τ' be the month and day 100 million years ago, we find

$$\frac{T'}{T} = \left(\frac{4 - \dfrac{2\pi}{\tau'}}{4 - \dfrac{2\pi}{\tau}}\right)^3;$$

and, substituting for T, τ, τ', their values,

$$\tau = 8{\cdot}9442 \text{ units};$$

$$\tau' = 8{\cdot}8406 \quad ,,$$

$$T = 27{\cdot}3217 \text{ days},$$

we obtain

$$T' = 27{\cdot}118 \text{ days}.$$

The difference between T and T' is only 4·896 hours; or, in other words, the month was only 5 hours shorter than at present 100 million years ago. This result shows that 100 million years was only as "yesterday" in the evolution of the earth-moon system.

The distance of the moon from the earth, at this time, is easily calculated; for, by Kepler's third law we have

$$\left(\frac{T}{T'}\right)^2 = \left(\frac{r}{r'}\right)^3, \tag{11}$$

or

$$\left(\frac{27{\cdot}322}{27{\cdot}118}\right)^2 = \left(\frac{60}{r'}\right)^3;$$

or,

$$r' = 59{\cdot}701 \text{ radii}.$$

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* *Proceedings*, *R. Soc.*, 19th June, 1879.

In other words, the moon's distance from the earth, 100 million years ago, would have been 99·5 per cent. of its present distance.

If the earth had a temperature equivalent to that of molten steel 100 million years ago, which was so small a fraction of the whole time of separation of the earth and moon, what must have been the temperature of the earth-moon when they began to separate? The present temperature of the sun is as nothing compared to it. *A fortiori*, what must have been the temperature of the sun when the earth-moon separated from him? There seem to me to be several "screws loose" in these "*Empirico-Cosmological*" speculations.

XV.—ON THE MODE OF OCCURRENCE AND WINNING OF GOLD IN IRELAND, BY GERRARD A. KINAHAN.

[Read March 20th, 1882.]

OF recent years improvements in metallurgical processes have rendered the production of silver a much cheaper operation than formerly, and as a necessary consequence, combined with an increase in the supply from other sources, that metal has deteriorated materially in value. This has increased the appreciation of gold, and rendered the sources from which it may be derived more worthy of consideration.

Attention has been directed to the more productive auriferous districts over the world; but although these, and the gold fields of Great Britain, have been described, no special account, so far as I can learn, has been given, in recent years, of the occurrence of gold in Ireland. I have, therefore, ventured to lay before the Society the following epitome compiled from the various published sources, and have endeavoured to bring the subject down to the present date.

Introductory Remarks.

In very remote times, gold was probably a production of Ireland, because in the annals numerous mention of this metal is to be found,* and in recent years the quantities of golden ornaments and vessels that have been exhumed from the bogs and prehistoric structures, would seem to strengthen this supposition.

Of these discoveries, one of the most remarkable is that in the Bog of Cullen, on the borders of the counties of Tipperary and Limerick, where not only golden vessels and ornaments, but also the crucibles, ladles, and other instruments, necessary for the working of that metal, have been found under a considerable thickness of peat. Of the finds in this bog, Vallancey gives an

* See Simon's Irish Coins, page 2, and Wilde's Catalogue of the Antiquities of Gold in the Museum, R.I.A., page 3.

extensive list of those discovered before his time * (1804). Concerning this place he makes the following observations :—

"It is remarkable that the antiquities were found *under the wood;* for that was removed at about six feet depth, and some of them were found very deep; that is near the natural soil on which the bog was formed. It was apparently a manufactory situated in a wood—in a valley—for the convenience of fuel for smelting. This wood had been blown down, and formed the bog in which these things had been found. A stratum of earthy bog had formed on this bog, in which grew another wood, which having been blown down like the former, had formed the upper bog of six feet above it."

This depth of peat probably represents an age since the relics were deposited, of between 2,000 and 3,000 years.†

Of other finds in later years some of the largest recorded seem to have been those at the ancient fords on the Shannon, from which they have been exhumed during the excavations for the improvement of the navigation.

In the ancient annals there is a record that may fix the date of the first working of gold in Ireland. Thus, in the Annals of the Four Masters, we find during the reign of Tighernmas, in the year A.M. 3656, the following entry :—

"It was by Tighernmas also that gold was first smelted in Ireland in Foithre-Airthir-Liffe. (It was) Uchadan, an artificer of the Feara-Cualann, that smelted it. It was by him that goblets and brooches were first covered with gold and silver in Ireland."‡

As a proof that Ireland, in early historic years, was rich in gold, Colonel Vallancey quotes the following passage from the history of Caen in Normandy, by M. Delarue :—

"The exchequer (*i.e.* of Caen) acquired very great consequence and extent when our Dukes became masters of Anjou, Poitou, Aquitane, the

* See "Collectanea de Rebus Hibernicis," by Colonel Charles Vallancey, vol. vi.; also "Manners and Customs of the Ancient Irish," by Eugene O'Curry, vol. iii., page 205 (lecture xxix.)

† See "Geology of Ireland," by G. Henry Kinahan, page 273.

‡ This is also recorded in the book of Leacan. Keating in his History of Ireland gives the date as A.M. 2816, and states that "this Tighernmas was the first who discovered gold ore in Ireland." The Leinster people were formerly called Laighnigh-an-Oir, or the Lagenians of the gold, "because it was in their country that gold was first discovered in Erinn," Foithre-aithir-Liffe was the main ridge of the Wicklow Mountains.

city of Caen was then the seat of the Government, not only of those provinces, but also of Great Britain. The exchequer of England was annually exhausted to fill the coffers of that of Caen, and according to the registers kept in the Tower at London, we find that the treasury of Caen received in one year, 23,730 marcs of silver sent by the treasury of London, besides 400 marcs of silver and 200 ounces of gold sent by that of Ireland—an enormous sum of money for those times."

Giraldus Cambrensis (Gerald Barry), who died about A.D. 1224, also states that Ireland abounded in gold.

The Irish for gold is *or*, which in the Anglicized names is corrupted into *ore*; the occurrence of this in some names of places in Ireland shows that these places formerly were connected with gold in some form or another, though many evidently refer rather to the worked metal than to its occurrence native.*

The following names, however, may refer to the occurrence native of the gold:—

Slieve-an-ore (Mountain of the Gold) near Feakle, Co. Clare: this name is also found in other parts of Ireland.†

Tullynore (Tully-an-ore) (Little Hill of the Gold), Down.

Coom-an-ore (Hollow of the Gold), between Bantry and Dunmanway, Co. Cork.

Lug-an-ore (Hollow of the Gold), near Clonmel, Tipperary.

Glan-an-ore (Glen of the Gold), Co. Cork.

The localities from which gold was to be obtained formerly seem to have been forgotten during the wars that from time to time troubled this Island; for it was not until many years after that we find a suggestion as to the occurrence of it; and not till recent years that any attempt was made to seek for it. Although the early Christians had abundance of gold, there are no records to show that gold mines were known in this country during the Christian Era.

Gold "in Situ" in Ireland.

The small quantities of gold that have been found in Ireland in recent years, seem to have been procured principally from alluvial deposits, or, what in California would be technically

* The word *ore* does not always signify gold. (See Joyce's "Irish Names of Places," second series, page 344.)

† Slieve-an-Aur or Slieve-an-Aura (Co. Antrim), now spelled Slieve-an-Orra (where gold has been found, see page 5), may have the same meaning.

termed, "placer mines." While gold *in situ* (*i.e.* in the original rock or matrix) even in minute quantities, is up to the present of rare occurrence, and few localities have been recorded. Of these may be mentioned:—

A quartz vein, in the Cambrian rocks on Bray Head, Co. Wicklow, which within the past few months has been proved auriferous by Mr. Francis Codd, at the Royal College of Science. This occurrence is of special interest, as it appears to be the first record of an *auriferous quartz vein* in Ireland. The rocks in which this vein occurs are green grits, and slates, across the strike of which it cuts at angle of about 60°. There would seem to be some similarity between these rocks and those of Merionethshire, where gold has been worked near Dolgelly and Barmouth.

The late Sir Richard Griffith, in his list of mineral localities in Ireland, states that the gossan of the Dhurode copper lode at Carrigacat,* on the south shore of Dunmanus Bay, is auriferous (Cork, Ordnance Survey of Ireland, six-inch maps, sheet 147.)

The pyrites of the Ovoca (co. Wicklow) mineral channel, has long been known to contain traces of gold, especially that of Ballymurtagh, Cronebane, and Connary. At Ballymurtagh the gossan is the richest part, but it is also found in the pyrites lode; it is also stated to occur in the ochre that separates from the drainage waters of these mines.

At Upper Cronebane and Connary there appears to have been a richer deposit, from which the gold was extracted, as M. Charles Coquebert, writing, about 1794, a description of these mines in the "Journal des Mines," No. XVI., states that at Liverpool, they extracted by liquation, from this pyrites, "a certain proportion of silver, and this silver contains 0·01146 of gold."†

In some parts of the lode at Ballymurtagh, Upper Cronebane, and Connary, an ore is found called "Kilmacooite," which has been described as "a peculiar combination of sphalerite, argen-

* There are specimens in the College of Science Museum from this locality. These specimens consist of "auriferous" gossan associated with hard white crystalline quartz containing "vugs" filled with yellow ochre.

† I am informed by Captain Argall that when the Wicklow pyrites was used extensively in England, from the pyrites ash an auriferous silver was extracted at St. Helens by a liquid process, which was worth from 8s. to 10s. per ounce; any Wicklow ore was used.

tiferous galena, iron and copper pyrites, and antimony glance, with a trace of gold."

M. Charles Coquebert speaks of this as follows:—

"At Connary, very near the high road, in the part of the vein which trends towards the North East, this vein enlarges much towards the surface of the earth, and contains a galena having a steely grain mixed with killas, very difficult to smelt, which produces about 25 per cent. of lead containing one and a half ounces of silver per hundred weight. The top of the vein produces in many places a substance like ochre, which contains about one-half per cent. of silver and a little gold."

Speaking of Upper Cronebane and Connary, Weaver evidently refers to this ochreous deposit in his description:—

"A brown indurated oxide of iron in the upper part of a metalliferous bed, in the higher grounds of Cronebane, containing minutely disseminated native silver which contained thirty grains of gold to the ounce—that is about six and one-fourth per cent."*

And a similar deposit was worked at Connary, about 1856, that contained from six to twelve ounces of silver and half an ounce of gold in the ton of material.

"Placer" Gold.

Of "placer" gold there are several records, while it is probable that the sands of many of our rivers, if carefully washed, would yield, if not traces of gold, other metals and minerals equally if not more interesting.

Gerard Boate, in his "Natural History of Ireland," written A.D. 1652, mentions that gold had been found in the sands of the Moyola river, which rises on the borders of Tyrone and Londonderry, and flows into the north-west corner of Lough Neagh. The geological structure of the country about the head-waters appears to be Silurian slate (mica slate), with some igneous rocks.

Gold is reported to have been found, prior to 1820, in the sands of the streams flowing from Slieve-an-Orra (Antrim, sheet 19) into

* He mentions that the plate of several of the county families was made of this rich alloy. In the parish church (Castlemacadam) the chalice belonging to the communion plate is stated to have been made of the same. On this piece is the following inscription:—

"The produce of Cronebane mines and gift of ye gentlemen of ye Company of ye said mines, to ye parish church of Castle M'Adam, A.D. 1753."

the Glendun river, which enters the sea at Cushendun.* The summit of Slieve-an-Orra is composed of basalt, but on the north and east slopes mesozoic rocks crop out, which rest on Silurian slate. From these older rocks it is to be supposed the gold originally came.

It has been reported that gold has been found near Ballinascorney Gap, county Dublin, and that the peasants from that neighbourhood have brought it in quills into Dublin. Small pieces have been picked up from the Dodder sands above Rathfarnham; and some years ago two small nuggets, each attached to quartz, were picked up in Stephen's Green, from gravel brought from that river. Another reputed locality is on the hills of the barony of St. Mullin's, county Carlow, where an old man is said to have obtained gold. Unsuccessful trials have been made here by Mr. Kavanagh of Borris.†

Small specks of gold were observed in a typical "black sand" from near Greystones, county Wicklow. It is possible a bed of this sand lies below the level of the beach hereabouts, as north of this a thin layer was seen on the top of the marl, exposed in a sinking made in connexion with the railway. Another locality where traces of gold have been observed, is the gravel of the Ovoca river, near Newbridge.

Weaver in his explorations found small quantities in the Ballycreen stream, also in Ballinagappoge (in the stream called the Mucklagh brook), both tributaries of the Ow, which unwater the south and west slopes of Croghan Moira. Mr. F. Acheson, I believe, found gold in the Ow river, above Ballymanus Bridge; while in Griffith's list of mineral localities, Killacloran, near Aughrim, is given as a gold locality. It has also been found at Ballycoog ford.

The principal Irish placer mines worked during recent years occur along the tributary streams of the Daragh water or Aughrim

* About 1825, it was proposed by the Glenarm and Antrim Mining Association to work this river.

† In 1868 there was a rumour that a 6lb. nugget, besides many smaller, were found at Crossmolina, county Mayo. In the list of exhibits at the Exhibition of Irish Manufactures in 1844 (see Proceedings Roy. Dub. Soc., Vol. 80), specimens of native gold and silver are mentioned as belonging to the Mining Company of Ireland. Where the gold came from cannot be ascertained; it is reported to have weighed 40 oz.

river, which itself is a tributary of the Ovoca, joining the latter at the lower "Meeting of the Waters," near Woodenbridge. These tributaries unwater the north and north-eastern slopes, valleys, and associated spurs of Croghan Kinshelagh. To the north-west, gold in very minute quantities has been found in the Ballythomas brook. This and the streams to the west and south were explored by the peasants, who probably washed only the upper river gravels; so that, as there is a deep deposit of drift in all the valleys, it is very possible, if a sinking had been made to the rock, gold in greater quantities would have been obtained.

Croghan Kinshelagh, *Historic Notes.*

It does not appear that there were any ancient gold diggings in this locality. It has been reported, however, that before the Government instituted workings here, during the last century, the ground in places had the appearance of having been previously worked.

The following early historical notes have been taken principally from the letters of Lloyd and Mills to the Royal Society, and the published reports of the directors (Weaver, Mills, and King) to the Government.

About 1765 the first recorded piece of gold was found here, by a man crossing the brook (Ballinvally); it was about the size of the head of a brass nail. This set many people looking for it, but it appears they were very unsuccessful, as they soon abandoned the search. However, a local schoolmaster, named Dunahoo, in 1770, used to seek after it in the early mornings, and he told his neighbours, amongst them Mr Graham of Ballycoog House, that gold abounded in some of the valleys. About the same time a piece was found by a boy, named John Byrne, when fishing; and it was also stated that some Dublin jeweller about this time obtained four or five ounces of gold annually for eleven or twelve years from a peasant of the vicinity.

After September, 1795, the wealth of the stream* between Ballinvally and Ballinasilloge became generally credited in the neighbourhood. One report states it was owing to a man finding a piece half-an-ounce in weight, while another is that a lump weighing

* This stream was then called "Aughatinavought." This name is now quite forgotten locally, having been supplanted by that of "Gold Mine river." (See Map, plate xxi.)

$1\frac{1}{2}$ pounds had been found in the upper part of one of the rivers but, as it was supposed to be copper, it remained for several years in the possession of a family named Byrne (who used it as a weight). However, about this time it was sold to an itinerant tinker, who again sold it to a jeweller in Capel-street, Dublin.

When the riches to be obtained from the valley became known, the peasants congregated from the surrounding districts to take part in the spoil, and "over 300 women, besides great numbers of men and boys, were engaged in the work." They continued in undisturbed possession at Ballinvally for about six weeks, obtaining, according to Mills, who wrote immediately after they ceased, about £3,000 (Irish) of gold (or as it sold for £3 15*s.* per oz., about 800 oz.). Mr. Graham, however, estimated it as £10,000 worth, or 2,666 ounces.

The work being quite novel, the peasants' method of extracting the gold was extremely rude, and after rain metallic specks were to be seen on the waste heaps, which subsequently afforded a profit on re-washing. They found that the richest place was from 200 yards below the Ballinasilloge ford to 150 yards above it. The largest nugget* they obtained is recorded as having weighed 20 oz. 2 dwt. 21 grs., but Mills mentions one as having been found that weighed 22 oz., others of 5 oz., and of 2 oz. 17 dwt.

In October (1795) the Government sent the Kildare Militia to occupy the place, "when the great concourse of people, who were busily engaged in endeavouring to procure a share of the treasure, immediately desisted from their labour and peaceably retired," or migrated to explore other streams.

The Government having obtained an Act of the Parliament of Ireland,† started regular streaming works in the August of the following year, 1796, under Messrs. King, Weaver, and Mills, who were directed—

"In the first instance, to endeavour to collect all the gold deposited, and thereby to remove every temptation for the assembling of mobs,

* This was weighed by William Molesworth, who found it to have the remarkably low specific gravity of 12 although worth £4 per oz.; he found it full of cavities and pores. Kirwan found the specific gravity of another piece to be 13.

† This was an Act "To enable the Lords Commissioners of His Majesty's Treasury to conduct the workings of a gold mine in the county of Wicklow," which received the Royal assent, 24th April, 1797.

whose numbers had before that time increased to a very alarming degree.

"Secondly.—To produce, if possible, a profit from the workings.

"Thirdly.—To ascertain whether the works should be proceeded upon or abandoned."

To carry out these instructions they proceeded to rewash the clay and gravel which "had been rudely washed by the populace," and to continue the works after the gold wherever it was found, till the depth of covering "had become so thick as to preclude the hope of gain from individual trials, conducted without order or regularity."

In the meantime the natives, who had been driven from their diggings in Ballinvally, were exploring the neighbouring brooks, but any discoveries they made they endeavoured to keep secret, because whenever the directors heard of one, they proceeded thither and instituted trials. These were, however, all abandoned after a short time, as none of the places appeared as favourable as the Ballinvally stream.

These stream operations were continued until May, 1798, when the labourers having deserted to join the insurrection, the mining plant was carried into Rathdrum to assist in fortifying a barrack, after which the insurgents burned the miners' huts.

Up to this period the gold obtained amounted to 555 oz., 17 dwt., 22¼ grs., which produced £2,146 15*s.*, and had cost £1,815 16*s.* 5*d.*

The gold is described as of a bright yellow colour and very malleable, about 22 carats fine; the alloy being silver with a little copper and iron. It had a specific gravity of from 12, that of the largest piece obtained, to 16·5, that of the fine grains; the low specific gravity being due to its porosity, some of the cavities containing ferric oxide and quartz. At that time its marketable value was £4 per oz.

[TABLE.

ANALYSES OF WICKLOW GOLD.*

	Gold.	Silver.	Iron.	Copper.	Silica.	Total.	Specific Gravity.	Authority.
A	$22\frac{58}{101}$	$1\frac{43}{101}$	—	—	—	24	12	Weaver's Assay.
B	$21\frac{6}{8}$	$1\frac{7}{8}$	$\frac{3}{8}$		—	24	—	Alchorne (Mint Master).
C	92·32	6 17	0·78	—	—	99·27	16·342	William Mallet.
D	91·01	8·85	—	—	0·14	100·00	14·34 15·07	D. Forbes.
E	89·00	8·10	2·1	trace.	—	99·20	—	Scott.

The low specific gravity is due to the porosity of the gold; A, was of a large nugget—C, small grains.

COMPARATIVE ANALYSES OF SOME QUEENSLAND GOLD.

Gold.	Silver.	Iron.	Copper.	Lead.	Bismuth.	Total.	Authority.
89·920	9·688	0·070	0·128	0·026	None.	99·832	Percy and Smith.
92·805	6·774	0·014	0·048	0·048	Trace.	99·684	Smith.

"The gold was found accompanied by other metallic substances dispersed through a stratum composed of clay, sand, gravel and fragments of rock, and covered by soil, which sometimes attained to a very considerable depth, from twenty to fifty feet, in the bed and banks of the different streams." In every instance where gold was found there was "also found fragments of *magnetic iron ore* and *quartz*, containing *chlorite*, *iron ochre* and *martial pyrites*, attended, more particularly at the works at Ballinvally, with *specular iron ore*, *brown* and *red ironstone*, *tinstone crystals*, *wolfram*, and grey ore of *manganese*." Tinstone was also found in Monaglogh and Coolbawn.

In some specimens quartz was adherent to the gold, the magnetite, and to the wolfram; and also the gold sometimes was found incorporated with wolfram and ochre.

Mr. William Mallet has since added the following minerals to these lists:—

Galena, titanite, calcopyrite, molybdenite, with the gems sapphire, topaz, zircon, and spinelle, besides some minute specks of a white metal that appeared to be platinum. It may also be remarked that on washing the sand, numerous little white

* For Welsh gold, see "Phil. Mag." (4) xxxiv., 831 and xxxviii., 821. Watts' Dict., 2nd Supp., 572.

spherical balls are found; they are evidently altered grains of shot, probably occurring as carbonate of lead.

In September, 1800, when the times became a little settled, mining operations were resumed, and in addition to the streamings extensive exploration works were undertaken in 1802. A level (to prove the quartz veins in depth) was driven 178 fathoms into the mountain, from above that place, on the Ballinvally stream, where the highest particles of gold were obtained (although unaccompanied here by the usually associated minerals), and where the quartz veins appeared most numerous, but although fifty or sixty quartz veins were crossed not a particle of gold was obtained. Furthermore, thousands of fathoms of open casts were cut along the slopes of the mountain, and "the mineral substances were subjected to the operations both of fire and of amalgamation, but in no instance was a particle of gold elicited from them, either by the one or the other process. So unsatisfactory a result led to the persuasion that the gold formed no part of the veins which appear in the mountain. The same conclusion seems to apply to the tinstone, wolfram, and manganese, in discovering which the mining operations equally failed."

In 1803, after the directors' unfavourable report, Government abandoned the enterprise; for although streaming works had proved profitable, the explorations had entailed a heavy loss. The total quantity of gold obtained by the Government amounted to 944 oz., 4 dwt. 15 grains, which produced £3,675 7*s.* 11½*d.**

Since 1803 this and several of the neighbouring streams have been worked systematically at intervals with varying success, but on the whole unprofitably. The peasants, between times, working the streams apparently with more satisfactory results. The records of all these workings are, however, scattered and scanty.

When Government abandoned their active mining operations, they left for a time a company of infantry to guard the place; but after these were removed the people resumed their search after the precious metal; and it has been estimated that about £2,000 worth of gold was sold annually by them in Dublin; others have estimated the whole produce as worth £20,000 during the time they continued working.

About the year 1839 or 1840 Government granted a lease for

* The total expenditure is stated to have been £6,907 14*s.* 2½*d.*

21 years, to Messrs. Crockford and Co., of all the gold that might be picked up. Extensive trenches were cut at right angles to the Ballinvally stream, and works undertaken in Moneyteige, besides working the Ballintemple stream; about fifty men were employed, but the workings were only continued for about four months—£1,800 worth of gold having been obtained. During these workings an 11 oz. nugget was obtained at Ballinasilloge, and from Ballintemple nuggets weighing 4 oz. 12 dwt. 10 grs. and 4 dwt. have been recorded.

In 1862* the Carysfort Mining Company obtained the gold royalties† of the district, and instituted extensive trials. They "costeened" the surface of the mountain to a considerable extent, while they collected, crushed, and examined the quartz of the district. "Some of the more promising lodes of quartz" were "pierced by shafts a couple of fathoms deep," but without finding a vein of gold-bearing stone. The researches which were made "into the deposits in the valley showed a wide distribution of the particles of gold. Of those particles which could be called nuggets, the larger were found at the upper parts of the streams towards their sources, and as they descended the streams the particles became more minute." This was not an "absolute rule, but was generally the case." The largest nugget found weighed 320 grains.

This company ceased operations after gold about 1865, and had obtained £203 6s. worth, after having sunk shafts upon and examined almost every known lode in the neighbourhood, without finding any gold in its original matrix or vein.

At the present time the royalty of the district is held by Mr. F. Acheson, who has been working for several years past, but discontinued mining operations a short time since. In the works carried on under him the richest deposit was found in the "Red hole," about 500 yards above the Ballinasilloge ford, on the old Arklow road.

* About 1849 an attempt was made by a Mr. Collett to work the district, but no mining operations seem to have been undertaken. During the working of the peasants in 1856, two nuggets were found, one weighed 6 oz. worth £30, the other 24 oz. worth £100.

† This Company was established early in 1859 to work the lodes of the district, but did not obtain the gold royalties till 1862. It appears that in 1860 Colonel Butler had obtained the gold royalties of 70,000 acres of this district, and Mr. Bullen the gold royalties of the vale of Ovoca to Arklow, but in neither case were active operations undertaken. Henwood states that they obtained 85 oz. altogether, but gives the period of working, 1857–1862. In the following table the quantities in parentheses are calculated from the value of the gold at the time.

Table of Workings at Croghan Kinshelagh.

—	Duration of Works.	Number of Ounces.	Value.	Largest Nuggets.	Remarks, Authorities, &c.
Peasants.	For 6 weeks to 15th Oct., 1795.	Estimated 800 oz. to 2,666 oz.	£3,000 to £10,000.	oz. dwt. grs. 22 0 0 20 2 21 5 0 0 2 17 0	Mills. R. Molesworth. Mills.
Government Workings.	12th Aug., 1796, to 26th May, 1798.	oz. dwt. grs. 555 17 22½	£2,146 15*s.*	18 ounces. 9 " 7 " 2½ "	Reports to Government by Mills, Weaver, and King.
	8th Sept., 1800, to 24th June, 1801.	oz. dwt. grs. 43 9 10	£ *s.* *d.* 112 14 11¾		
	June, 1801, to 1803.	oz. dwt. grs. 344 17 6¾	£1,415 18*s.*	1,507 grs.	R. D. S. nugget.
Peasants.	To 1839.	(5,000 oz.)	£20,000	4½ ounces.	Estimated in 1840.
Crockford's Company	4 months (1840).	(600 oz.)	£1,800	11 ounces.	Return to Woods and Forests.
Peasants.	To 1857.	(?)	(?)	24 oz. & 6 oz.	Hugh M'Dermott, Arklow.
Carysfort Mining Co.	1862 to 1866.	(oz. dwt. grs. 52 11 5)	£203 6*s.*	320 grains. 105 " 83 "	Geological Society. Directors' Report.
Recent workings.	1876 to 1879.	oz. dwt. grs. 14 3 0	£60.	(?)	Mineral Statistics.

Total produce since 1795 may be estimated at between 9,390 ounces and 7,440 ounces; value between £36,185 and £28,855.

Physiography of Croghan Kinshelagh.

Croghan Kinshelagh may be regarded as the central portion and summit of a rather isolated tract of high ground, that rises to an elevation of 1,987 feet above the Ordnance datum, on the borders of the counties of Wicklow and Wexford, which sends out spurs and knolls from the main mass, each bearing a distinctive local name.

The body of the mountain is composed of sub-metamorphic Lower Silurian slates (argillite or chloritic and talcose clay slate), which strike generally about N. 45° E., and dip at about 70° to the S.E. Through these sedimentary rocks are various eruptive

rocks, of which, broadly speaking, those in the south-west spur are plutonic, and those to the north volcanic. In many places both the sedimentary rocks and eruptive dykes have undergone a peculiar change or decomposition, being altered into soft friable red and yellow clays, but in which the original structure is still apparent. This is evidently a chemical metamorphosis, and appears to have been either an impregnation of the rocks with iron salts, or a decomposition of those already present, probably a combination or alternation of both.

The superficial deposits consist of various depths of meteoric or local drift, the result of the disintegration of the upper portions of the underlying rocks; over this in places a thin covering of peat, while in the valleys there are old river gravels and alluvial deposits.

The proved auriferous valleys lie to the north and north-east of the summit of the mountain, the principal and central one at the base of the eastward slope of the northern spur, which comprises the hills of Moneyteige (1,892 feet) and Ballycoog (1,169 feet), in the rocks of which are lodes of magnetite, pyrite, calcopyrite, and galena.

The Occurrence of the Auriferous Gravels.

In the south Wicklow district the valleys that have been proved auriferous have all very similar physical and geological characters; they are comparatively narrow, with very steep and abrupt sides, on which there is usually only a scanty covering of soil. The bottom of the valleys are comparatively level, formed of alluvial deposits and local drift, that appears to have been derived from the wasting away of the sides of the original chasm in the rock. These general features become modified on ascending the streams.

The gold has been found principally in an ancient river gravel associated with the minerals previously mentioned, which make up the "black sand" resting on the "bed rock" at the bottom of the old valley and under the local drift, in which, and the more recent river deposits, it is distributed but sparingly. The auriferous deposit is richest at the lower portions, especially

where large stones occur, under and around which a very rich accumulation was often found,* as if due to the eddies that were produced by them in the ancient stream. On the bed rock the gold almost invariably occurs in "strings" or "leads," which form rich accumulations at the large stones mentioned above, and also in the hollows that are formed at the intersections of joints and breaks; and Kirwan has remarked that the deposit was most productive in the more level parts of the valleys, at the angles of the streams, and especially at the confluence of the streams, and also where the stream crosses the strike of the rocks.

The Auriferous Streams.

The following streams are those that have been systematically searched in this district.

The Ballintemple stream falls into the Daragh water on its right bank, about a mile north-west of Woodenbridge, it was worked first by Crockford and Co., and subsequently by the Carysfort Company.† Besides small gold, numerous small nuggets were found. The waste heaps are traceable from the Aughrim valley, up to a short distance above the "Bride's Well."

The Gold Mine River, however, is the principal auriferous stream, and enters the Daragh water at Woodenbridge; about a mile S.W. from which this stream bifurcates; and, for convenience in describing its branches, we will adopt the names applied by Weaver to them respectively, Western and Eastern or principal, auriferous streams. Below their junction the deep gravels of these rivers have not been explored.

The Western Auriferous stream or "Gold Mine River," is formed by the junction of three rivulets (draining the north-eastern slopes

* This was so well recognized by the old diggers, that if they came on one towards night they would watch it till morning, fearing lest it might be robbed. The usual large stones in these valleys are the Greenstones from the adjoining hills. Besides the riches on the bed rock, in one place a thin seam of clay occurred in the gravel, above which there was a rich accumulation of "black sand," besides that found below it.

† It is an interesting fact that the gravels of many of these streams, after being allowed to rest for a time, paid for re-washing. The machine usually employed was "The Long Tom," and it was no uncommon thing for the local diggers to pan the sand from the mouth of the Company's Tom, and obtain a fair return from it—one notorious digger, Regan, obtaining £5 worth on one occasion. The machine used at the Government workings is described in the "Transactions Royal Dublin Society," Vol. II., and there is an interesting picture of the workings in the Museum.

of Croghan Kinshelagh), a short distance above the bridge of Ballinagore. At their confluence, Weaver obtained some small gold, but not accompanied by the usually associated minerals. Above this he drove a level 178 fathoms to the north-west to prove the quartz veins in depth, while, in continuation of the stream works, an open cut was carried up the slope of the hill towards the south-west. At Ballinagore bridge he made an open cut on the right bank of the stream, that proceeded about a mile to the south-east, while another cut was made about 600 yards lower down, at the "Red Hole," on the left bank of the stream, that proved the ground to the north-west, as far as the top of the ridge bounding Ballinasilloge and Moneytiege. The river here is called in Weaver's Memoir the Ballinvally stream; it was formerly *Aughatinavought*. It was proved continuously along this part of its course, but except the little gold found above the bridge, no gold was found by Weaver above the Red Hole. From this, for about 400 yards down the stream, the richness of the deposit must have been very great, when we remember that it was here the peasants worked, while that subsequently Weaver found it the most productive working; also, that since then it has been worked by Crockford and the Carysfort Company, and the upper portion, of late years, by Mr. F. Acheson.

Lower down this stream, the remains of old workings are to be found at intervals, to within about 400 yards of the junction with the eastern auriferous stream. In a small tributary that enters on the left bank flowing from Ballykillageer (old name, Aughanarragid,* or the Silver or Money brook), the old workings extend up to the old Arklow road.

The Coolbawn stream flows north from Croghan Kinshelagh, between Coolbawn and Moneyteige, by Kilpipe, to join the Daragh water at Annacurragh. In this stream, at the confluence of its upper branches, Weaver found a 2½ ounce nugget—the largest he got anywhere except in Ballinvally. Here, also, he found some tinstone, and one of his trenches was opened up the western branch, and nearly round the summit of Croghan, without finding any gold. Subsequently, the eastern branch has been profitably worked. This stream does not appear to have been worked

* This name—pronounced as spelled above—is still used by some of the older inhabitants.

for more than about 500 yards below the junction, and it was worked mostly by the local inhabitants.*

The Eastern Auriferous stream is formed by the junction of the Killahurler stream, with the stream separating Mooreshill from Ballinvally and Knockmiller. The latter stream was proved by a branch of Weaver's Ballinvally trench: no gold has been recorded from it except a small nugget found by Mr. Acheson, near where it is crossed by the Arklow road. (This ford was formerly called Aughatinagat, which name is now disused.) In the eastward branch or Killahurler brook, Weaver made some trials and found some gold, but as the place was not promising he abandoned it.

From the confluence of these branches down to the Lyra (*anglice*, fork), a fair supply of gold has been obtained, while at Lyra a rich deposit was found—some of which was large gold. In the stream that comes in on the right bank at the Lyra, there are old workings for some distance up stream; and in the Monaglogh stream, coming in a little lower down on the same bank, large gold was also found. In the main stream, extensive workings have been carried on as far down as Rostygah, while in the stream separating this townland from Monaglogh, workings were prosecuted by Weaver, but only small sparks of gold obtained.

None of the dry ravines or "gulches" appear to have been explored in these valleys.

Résumé of Opinions on the probable Source of the Gold.

Notwithstanding all the trials and explorations which have been undertaken in the district, it has never been proved where the gold, and such of the associated minerals as tinstone and wolfram, occur *in situ*; because, as the alluvial deposits were followed up each stream, the gold in general became larger and more abundant, but suddenly ceased, or was only to be found in minute quantities, while the trenches opened above these places, also those cut at right angles to the streams above these rich deposits, failed to throw any light on the subject.

Mills, on account of the richness of the deposit at the ford of Ballinasilloge, was of opinion that north-west of this, some of the

* Griffith's gold locality, Killacloran, is probably on the lower waters of this stream, if not on the Clone stream to the North.

quartz veins would prove auriferous, on which account he proposed to drive a gigantic level—starting from below the "Gold Mine Lodge" (the house near the ford), and proceeding northwesterly to pierce the ridge of Ballinagore. This was never executed, but these veins seem all to have been cut, by the trench opened from the "Red hole," along the boundary between Ballinagore and Ballinasilloge, while Crockford's company are stated to have made open casts at right angles to the stream without being more successful.*

Weaver's suggestion was that these minerals occur disseminated widely, though in minute quantities, through the rocks of the mountain. He, however, acknowledged that the exploration works did not support this opinion in any way, only giving negative evidence of where the gold was not to be found.

Dr. Bartholomew Lloyd, in his first address as president of the Dublin Geological Society, showed that as the rich deposit was so local the explorations might have been confined to the vicinity of that deposit.

Professor Warington W. Smith (in "The Records of the School of Mines": Vol. I., pt. iii., 1856) when writing of the lodes of Moneyteige and Ballycoog, states that he is "inclined to infer that it was the back or upper part of these lodes, the waste of which furnished the greater part of the alluvial metallic substances found in the valley below, and amongst them the gold." Weaver had made unsuccessful trials on these lodes, and the Carysfort company were not more fortunate in their trials on these and many others in the district, not even a trace of gold being found. So that unless the gold was rich in the upper portions, and altogether absent in the parts remaining, it is difficult to feel convinced that these are the sources, although it must be remembered that the pyrites at Ballymurtagh and Connary, further eastward on the same mineral channel, are slightly auriferous.

At a meeting of the Royal Geological Society of Ireland, in 1865, when a discussion took place on this district, it seems to have been generally supposed that the matrix of the gold would be found in the quartz reefs of the district.

* There is a deep cut through the village of Ballinasilloge down to the ford, but there is no record by whom executed—probably by Crockford.

Considerations on the Occurrence of the Gold.

Gold is known to occur in the gossan and also in the pyrites lodes at Ballymurtagh, though only in minute quantities, it also occurs in certain parts of the same mineral channel at Cronebane and Connary, but no "streamings" have ever been attempted in the gravels of the adjoining valleys and ravines. Traces of "black sand" have been observed in the gravels of the Ovoca below Newbridge; and as this valley cuts across the main mineral channel, it is not improbable that some sands, especially the deeper ones in it and its tributaries, may yet be proved to contain gold in fair proportions.

A continuation of this same mineral channel extends along the ridge overhanging the Gold Mine Valley, but no gold has been found in any of the lodes hereabouts.

That the auriferous vein or lode wherever it exists, has a quartz gangue, and contains many of the minerals found associated together in the valleys, appears to have been proved by the specimens collected by Weaver, who not only found gold and wolfram each attached to quartz, but also found them incorporated together and with ochre.*

The Carysfort company, in searching for this quartz lode, I am informed by Captain P. Argall, "about twenty-four years ago calcined and stamped three or four hundred tons of quartz at the Ballintemple mines, near Woodenbridge. This quartz was collected from all parts of the adjacent mountain, from loose blocks and from various outcrops of quartz veins intersected in the levels driven in search of lead and other ores, at the Moneyteige and Ballintemple mines. After calcination the quartz was stamped and amalgamated, and, as far as I can remember, *not a particle of gold was obtained.*"

From the spongy and porous condition of the gold, particularly the larger pieces, it may also be inferred that the lode probably contains much pyrites with which the gold was intimately blended, which having become decomposed is now only represented by the

* Fraser, in his Statistical Survey (1801), mentions these specimens attached to quartz, and accounts for their rarity by the fact that, as the peasants sold the gold by weight, all useless minerals were first detached. Also, Mr. J. Knight Boswell, stated (1865) that he had "a piece of quartz with gold all round it," but adds that it "was evidently the effect of water."

ochre found in the cavities of the nuggets. The specific gravity of the specimens varied from 12, that of the largest nugget, to 16, that of the fine grains, although the gold was 22 carats fine. The specific gravity of fine gold being 19·4, that of gold of the composition of that of Wicklow should be about 18.

While considering what is to be inferred from the distribution of the gold in the valleys, it is well to remember that the deposit in which it occurs is a recent one, and that the several water basins were necessarily, during the deposition of the gravels, very similar in extent and configuration to what they are at present; also, that at least towards the close of the period, the general features of the district were like what they are now, except perhaps a little more rugged and steep. The principal changes that have taken place since then, being a rounding and smoothing down of the hills and a filling up, especially the lower parts, of the valley.

From the nature of the gravel and the worn surfaces of the underlying rock, it is evident that a rapid current flowed down these valleys at some former period. Although the gold and associated minerals are now most abundant at the bottom of the gravel, it is not necessary that they should be deposited first —while the upper and poorer portions accumulated at a later time—because while the gravels were thoroughly flooded with water, the natural tendency of the finest and heaviest portions would have been to work their way downward towards the bed rock; and during heavy floods, the lighter portions on the surface would be carried forward, leaving the heavier higher up the stream.

The gravels in the lower lying portions of the adjoining valleys show that at one time these were estuaries; but as no sinkings have been made in the deep gravels of the auriferous streams, it is impossible to say whether they were estuarine or not when the deposition of the gold took place in the upper reaches.

The occurrence of the largest pieces of gold, with a greatest abundance of the associated mineral substances, particularly the tinstone, below certain points on each of the streams, above which they were either absent altogether or only traces of gold were to be found without the usually accompanying minerals, suggests each of these places being in the neighbourhood of the lode. Further-

more, as these places in the three principal streams are nearly in a straight line, the direction of which is at an angle of about 70° across the general direction of the beds, we might expect hereabouts the presence of a "caunter lode" that is not conformable to the strike of the strata,* or it may be that the auriferous veins are conformable to the main lodes (and to the strata), and are cut off by a fault on the line of the supposed caunter lode.

Most of the gold is apparently rolled as though it had been drifted. But some of the smaller grains or "eyesills," especially in the upper portions of the streams, are frosted or crystallized; and Weaver found some specimens "crystallized in octahedrons, and also in elongated garnet dodecahedrons," which would suggest either that the gold has not been carried far from its vein or lode, but was freed from its matrix near where it is now found, probably by the disintegration of an enclosing pyrites quartz. Or that it grew, or rather crystallized out, where it is now found.

If the latter supposition can be entertained it seems necessary that the gold should have been carried in solution and deposited in the drift. But to obtain a natural solution of gold presents many difficulties. In the first place the obtaining of a solvent, and secondly, the keeping of the gold in solution; especially if it be derived from a pyrites lode undergoing decomposition; the first stage in the oxidation of such being the formation of protosalts (especially of iron), in the presence of which it would be impossible that the gold could remain in solution; but if there were such a solution percolating the rocks, when it issued from under ground and mingled with waters containing easily oxidizable substances the gold, becoming reduced, would be precipitated. In a paper read before the Chemical Society in 1879, Mr. George Attwood, F.G.S., from his experiences in South America, states that nuggets do gradually increase in size owing to the accumulation of finely precipitated gold.† It has been advanced that

* Most of the exploration works carried out seem to have been projected on the supposition that the auriferous lode ran in the same direction as the principal lodes of the district, which is about N. 40° E. to N. 45° E.; there is another small system of lodes nearly at right angles to this, as Ballintemple, Clonwilliam, and some of the Moneyteige lodes.

† On the growth of gold, see Phillips, Proceedings Royal Society, Vol. XVI., page 294, and Skey, Chemical News, Vol. XXX., page 172.

the fact that the apparently exhausted gravels afford on rewashing a fresh supply of gold is a proof that it grows there. This, however, is more probably due to weathering and disintegration, as at Goldhill, North Carolina, where apyritous quartz is crushed to fine sand, amalgamated, and the gold extracted; this sand after lying for about a year is again amalgamated, and yields a crop nearly equal to the first, and this operation may sometimes be repeated four or five times.

In conclusion, we may consider what probabilities there are as to any quantity of gold remaining undisturbed in the county.

In the recognized auriferous valleys the peasants worked in the shallow deposits, and all subsequent explorers appear to have been unwilling to break new or deeper ground; while Weaver was directed only *to continue the workings till the covering became deep enough to prevent the peasants working it profitably.*

It appears that there are yet places in the county where trials might well be undertaken with a fair chance of success, such as:—

I. The shallow deposits or gravels (*shallow placers* of the Californian diggers), on the tributaries of the Ovoca river. It appears remarkable that Weaver did not seek after some of these in connexion with his own mine (Cronebane), although portions of the lode were known to be auriferous. His trials round the summit of Croghan Kinshelagh, and his choice of the streams of Croghan Moira, seem to suggest that he had some peculiar idea as to the occurrence of the gold.*

II. The "bench diggings," *i.e.*, placers on the narrow benches on the slopes of the valleys above the present level of the rivers; these have not been looked for in any of the valleys of this district, nor are there many places where they could exist.

III. The deep gravels in the Ovoca river and its tributaries; the Daragh water and Gold Mine river:† these deep gravels have never been explored, although Fraser in his statistical survey (1801), recommended the estuarine flat above Arklow as a proper

* Captain P. Argall, who conducted the Cronebane mine for some time, informs me that "the Connary Mining Co. crushed and amalgamated a considerable quantity of quartz collected from the neighbourhood of their mines without obtaining any gold."

† Such accumulations could scarcely be analogous to the *deep placers* of California, which are in the ancient river system, above the present system of the country, often crossing it.

place for a trial. Higher up the rivers there are, however, places more favourably situated for such explorations.

IV. Quartz reefs in the Croghan Kinshelagh district, and other favourable localities. It has already been pointed out that no auriferous vein or lode has been found, the explorations only having narrowed the limits of its possible occurrence. If one lode or vein were proved auriferous, it would show to what system the auriferous lodes belong, and remove the difficulty of concluding whether they be auriferous continuously or only locally.

For more detailed information on the Wicklow Gold Mines, see Philosophical Transactions for 1796, and Royal Dublin Society's Transactions for 1800, 1801, 1802. Also Geological Society's Transactions, Vol. V., and Philosophical Magazine, 1835; Kane's Industrial Resources of Ireland, Calvert's Gold Rocks of Great Britain, Geological Society of Ireland, Vol. IV., page 269, and Vol. I. (N.S. 1865), page 97, Quarterly Journal of Science, Vol. XV., p. 189; also Mining Journal, Vol. X, p. 30 326; XI., p. 47, 213; XIX. p. 15; XXVI. p. 585, 658; XXXV. p. 472.

XVI.—CATALOGUE OF THE EXAMPLES OF METEORIC FALLS IN THE MUSEUMS OF DUBLIN, BY PROF. V. BALL, M.A., F.R.S.

[Read May 15th, 1882.]

THE present paper is the first of a series which I hope to publish from time to time, giving an account of various collections which are preserved in the Geological Museum of Trinity College. Where possible, and when the necessary permission is obtained, I intend to include information regarding collections in other Museums besides that which is under my own charge. The publication of such lists has for its object the conveyance to those likely to be interested, information regarding the existence in our Museums of authentic examples of the specimens indicated, and I am not without hope that it may lead to our series being made more perfect by donations and exchanges. Possessors of single examples and small collections, may be induced to contribute them to Museums if they receive the assurance that they will be well cared for.

Far removed in size and importance as the collection here described is from those which are preserved in the British Museum, in the Imperial Museum, Vienna, and in the Indian Museum, Calcutta, it serves sufficiently well to illustrate the leading forms and lithological characters possessed by these interesting objects—objects which are now, perhaps, more than at any previous time, exciting interest and attention, owing to the fact having been recognised that they afford, as it were, hand specimens of what our earth was when it first consolidated, and before organic life made its appearance.

Ireland has contributed only four examples; these all belong to the class of aerolites, and the circumstances attending their falls, respectively, are on record. A fifth fall was reported to have taken place at Cloneen, near Parsonstown, King's county, in August, 1828. A sample preserved in the National Museum is accompanied by a statement that "the fall caused the death of two men, injury to a woman, and the ignition of a stack of oats." No one having any knowledge of the appearance presented by meteorites could possibly regard this sample as being other than spurious. It is in fact, in all probability, a fragment of slag from some smelting furnace. The injury described was probably caused by a flash of lightning.

The four authentic falls are—

1. Mooresfort, Co. Tipperary,	August, 1810.
2. Adare, Co. Limerick,	September 10, 1813.
3. Killeter, Co. Tyrone,	April 29, 1844.
4. Dundrum, Co. Tipperary,	August 12, 1865.

The Killeter fall is described as "a shower of aerolites," but no specimens are preserved in our local Museums, and there is only a small one weighing 2·7 grammes in the British Museum, and another of about the same weight in the Calcutta Museum.

It may be convenient to quote here for easy reference the published analyses of these falls.

MOORESFORT, *Prof. Higgins,* Proceedings, Royal Dublin Society, Vol. XLVII., 1811.

Silica,	48·25
Iron,	39·
Magnesia,	9·
Sulphur,	4·
Nickel,	1·75
	102·

ADARE, *Dr. Apjohn,* Transactions, Royal Irish Academy Vol. XVIII., 1839, p. 17.

Iron and Nickel,	23·07
Magnetic Pyrites,	4·38
Chrome Iron,	3·34
Earthy Matrix,	68·47
Alkalies and loss,	0·74
	100·

KILLETER, *Rev. Dr. Haughton,* Proceedings, Royal Irish Academy, Vol. IX., 1867, p. 341.

Hornblendic Mineral (insoluble in acid),	34·18
Earthy Mineral (soluble in acid),	30·42
Iron,	25·14
Nickel,	1·42
Sesquioxide of Chrome,	2·70
Cobalt,	trace
Magnetic Pyrites,	6·14
	100·00

DUNDRUM, *Rev. Dr. Haughton*, Proceedings, Royal Irish Academy, Vol. IX., 1867, p. 336.

Nickel Iron,	20·60	Iron, 19·57; Nickel, 1·03
Sulphur Iron,	4·05	
Chrome Iron,	1·50	
Chrysolite	33·08	
Earthy Minerals, insol. in HCl.,	40·77	
	100·	

The weights are given in grammes, as in the British Museum Catalogue.—1 gramme = 15,432 grains.

—	Date of Fall or Find.	Weight in Grammes.
I. AEROLITES (ASIDERITES AND SPORADOSIDERITES.)		
1. BENARES, India. Probably a portion of the so-called Krakhut fall of December 19, 1798. Fractured surface partly glazed,	—	115·9
L'AIGLE, Orne, France,	April 26, 1803,	15·9
2a. Do. Sample in Museum of Science and Art, Dublin,	Do.,	218·
3. WESTON, Connecticut, U.S.A.,	December 14, 1807,	6·4
3a. Do. do. Sample in Museum of Science and Art, Dublin,	Do.,	51·7
4. STANNERN, Iglau, Moravia,	May 22, 1808,	11·7
4a. Do. do. Two samples in Museum of Science and Art, Dublin,	—	265·
5. MOORESFORT, Co. Tipperary. Sample in Museum of Science and Art, Dublin. Also a cast of original stone,	August, 1810,	1255·5
6. CHARSONVILLE, near Orleans, France,	November 23, 1810,	14·8
7. BERLANGUILLAS, near Burgos, Spain,	July 8, 1811,	21·6
7a. Do. do. Sample in Museum of Science and Art, Dublin,	—	13·8
8. CHANTONNAY, Vendée, France. Sample in Museum of Science and Art, Dublin,	August 5, 1812,	11·
9. LIMERICK (Adare, Faha, &c.),	September 10, 1813,	155·
9a. Do.,	Do.,	67·1
9b. Do. Sample in Museum of Science and Art, Dublin,	Do.,	134·9
10. DURALA, Patiala, India. Cast in Museum of Science and Art, Dublin,	February 18, 1815,	—
CHASSIGNY, near Langres, France,	October 3, 1815,	8·7
11a. Do., do., Sample in Museum of Science and Art, Dublin,	Do.	16·3
12. NANJEMOY, Maryland, U.S.A.,	February 10, 1825,	38·9

—	Date of Fall or Find.	Weight in Grammes.
13. FORSYTH, Georgia, U.S.A., ...	May 8, 1829, . . .	6·5
14. CHANDAKAPUR, Berar, India, ...	June 6, 1838, . . .	2·7
15. COLD BOKKEVELDT, Cape of Good Hope, . .	October 13, 1838, . .	2·7
16. CHATEAU REYNARD, Loiret, France, . . .	June 12, 1841, . .	8·2
16*a*. Do. do. Sample in Museum of Science and Art, Dublin, . .	Do., . .	16·6
17. BISHOPVILLE, S. Carolina, U.S.A., . . .	March 25, 1843, . .	1·9
17*b*. Do. do. Another sample? fragments and dust, ...	—	7·9
18. NEW CONCORD, Muskingum Co., Ohio, U.S.A., .	May 1, 1860, . . .	4·8
19. DHURMSALA, Punjab, India, ...	July 14, 1860, . .	216·3
20. BATSURA, &c., Champaran, India. Casts of separate fragments, ...	May 12, 1861, . . .	–
21. DUNDRUM, Tipperary, ...	August 12, 1865, . .	2158·7
21*a*. Cast of ditto in Museum of Science and Art, Dublin,	—	—
22. MASSACHUSETTS. History of this fall not known, .	—	4·8
II. SIDEROLITES (SYSSIDERITES.)		
23. KRASNOJARSK, Siberia. Known as the Pallas Iron,	Found, 1772, . .	4·4
23*a*. Do., do., do., .	—	9·6
23*b*. Several samples in Museum of Science and Art, Dublin, ...	—	—
24. BREITENBACH, Bohemia. Cast, ...	„ 1861, . . .	—
25. ESTHERVILLE, Emmet Co., Iowa, U.S.A., . .	Fell, May 10, 1879, .	1·9
III. SIDERITES (AEROSIDERITES.)		
26. SCRIBA, Oswego Co., New York, U.S.A., . .	Found, 1814, . . .	16·1
27. LOCKPORT, New York, U.S.A., ...	„ 1818, . . .	5·4
28. BURLINGTON, Otsego Co., New York, . . .	„ 1819, . . .	16·1
29. WALKER (or MORGAN ?) Co., Alabama, U.S.A., .	„ 1832, . . .	10·4
30. RÖWTON, near Wellington, Shropshire. Cast, .	Fell April 20, 1876, .	—
31.* TENNESSEE, U.S.A., ...	—	24·1
32.* Do., do., ...	—	11·4

NOTE.—There is a small sample of the Ovifak (terrestrial) iron in the Museum of Science and Art, Dublin.

* The labels on Nos. 31 and 32 do not show to which of the known Tennessee finds the examples belong.

XVII.—PALÆOZOIC ROCKS OF GALWAY AND ELSEWHERE IN IRELAND, SAID TO BE LAURENTIANS. By G. H. KINAHAN, M.R.I.A., &c.

[Read May 15th, 1882.]

It is well known to Irish geologists that Jukes, years ago, suggested that some of the rocks of Donegal might be of Laurentian age; while King, of Galway, made a similar suggestion in reference to the rocks of Bennabeola, or the Twelve Pins* of Connemara. Jukes published this opinion in his geology (1862), to which I refer in the "Geology of Ireland." Subsequently, T. Sterry Hunt, in a paper on metamorphic rocks read before the Royal Geological Society in 1863, stated that many of the Donegal rocks appeared to him to be lithologically identical with those of the American Laurentians; while at the same time he pointed out that other rocks from the same area "cannot be distinguished from those which characterize the altered Palæozoic strata of America," which are later than the Laurentian.

In March, 1881, after the question of the possibility of Laurentian rocks occurring in Ireland was mooted by Dr. Hicks and others, I wrote a paper pointing out all the different tracts of old rocks in Ireland having lithological characters more or less similar to those of the American Laurentians, but at the same time I showed that they were also very similar to the American metamorphosed Huronians. (Lower or Cambro-Silurians).† Dr. Hicks had previously suggested that my "supposed upper Cambrians," in the county Tyrone, to the eastward of Omagh, might be Laurentians; while still more subsequently Drs. Callaway and Hull published that they had discovered Pre-Cambrians in Wexford, Mayo, and Donegal.

Counties Donegal, Tyrone, and Mayo.

In connexion with the Donegal rocks, I have carefully studied all the statements published, and cannot see that their claim‡ to the title of Laurentians has been satisfactorily proven; on the con-

* Called Twelve Stacks or Pins "by the mariners coming in from the maine" (O'Flaherty, History of Hiar Connaught).

† The MS. of this paper was mislaid, and consequently it did not appear in the "Geological Magazine" until September.

‡ Dr. Hull. Scientific Transactions, Royal Dublin Society, Vol. i., Ser. ii., page 243.

trary, some of the facts put forward would seem to imply that the gneiss is only a portion of the rock-formations of the district, which has been more metamorphosed than the rest.

Dr. Hull declares that he has carefully examined the boundary between the supposed older and younger rocks. He is obliged to have recourse to the supposition that there is not only an unconformability, but even a "double hiatus" between them; but no substantial evidence for an unconformability is given. He acknowledges that there are various lines of fault bounding the more metamorphic rocks; and concealed faults often cause a delusive appearance of unconformability. It is a common occurrence, well known to those who have studied metamorphic regions, that the more altered rocks often lie against the less altered. Rocks of both these classes will be found in places in West Galway, in the area now said to be occupied by Laurentian rocks. Moreover, in the "Geology of Ireland" I have described and mapped some interesting patches of such, more intensely altered rock, near the Ovoca mines, county Wicklow. These are patches of "baked rocks" (paroptetic), but in the same district, at Carrig, a few miles to the northward, may be seen granitoid gneiss bounded by similar lines of breaks; and the published descriptions of the lines of boundaries of the Donegal gneiss would be applicable to many fault boundaries in all metamorphic regions.

In America and Scotland basal conglomerates prove the unconformity between the Laurentians and the newer rocks, but neither in Donegal, nor with the rocks of Tyrone, N.E. of Omagh,* nor in the Ox Mountains, or Slieve Gamph, nor in N.W. Mayo, near Belmullet, *have such conglomerates been recorded, although two great hiatuses are supposed to exist between the old and the younger rocks.*

If these rocks, from their lithological characters, are to be classed as Laurentians, why are others of similar characters, and

* These and the overlying unaltered fossiliferous rocks were originally said to belong to the one group: but after I had shown that this was impossible ("*Supposed upper Cambrian rocks in the counties Tyrone and Mayo.*"—*Proc. Royal Irish Academy*, 2nd *Ser.*, *Vol. iii. Science, p.* 343), Dr. Hull has suggested, first, that they are the lowest portion of the Cambro-Silurian, that is the Arenig group, and afterwards that they are Laurentians. In either case it is stated that my supposition is probably wrong; although my statement is; they "*are probably equivalents of part of the Arenig group*" *of Wales, put by some geologists among the Cambrians.*" And among these Geologists are Lyell and Ramsay.

very similarly circumstanced, to be differently treated? Such as the rocks in the neighbourhood of Petigo, on the north of Lough Erne, as also the rocks of the small tract in N.E. Mayo, southward of Charlestown, which in Griffith's and Jukes' maps are marked as metamorphic rocks; but which are grouped in Dr. Hull's maps with the overlying unmetamorphosed fossiliferous upper Silurians. In these metamorphic rocks the granitone is very similar to some of the Laurentian rocks.

As the principal object of this paper is to treat of the tracts with which I am more especially acquainted, I will not now dwell further on the rocks of the above areas; especially as the arguments and facts already put forward elsewhere, in favour of their being of Cambrian age, remain unanswered.

COUNTY WEXFORD.

The Wexford rocks mapped by me as Cambrians are divided into two areas by a trough of Carboniferous rocks. In the area to the S.E. of this trough or band, which may be called the *Carnsore district*, the rocks, as a general rule, are more altered than those to the N. and N.W. of the band. No one can positively assert that the rocks at both sides of the band are of the same age; but, on account of the similarity between some of the rocks in the Ballycogley section, and some of those northward of the band, I believe all belong to one group; and those to the northward of the band are evidently Cambrians, as they contain the characteristic fossil, *Oldhamia.* Dr. Callaway, indeed, does not separate the rocks northward and southward of the band; but he would wish to divide those in the *Carnsore district* into groups of distinct ages. The rocks in this area are not well exposed; but by combining the sections on the coast at Crossfarnogue and Kilmore Pier, with those at Ballycogley, near Lady's Island Lake, and that along the east coast, a very fair section across the whole can be constructed; from which we learn that there is a gradual merging from granite, through gneiss, into schist, as the rocks are followed northward from the south coast. Dr. Callaway suggests that there is an unconformability in the Crossfarnogue section; but this is impossible. He also states that the unconformable boundary of the mass of metamorphosed eruptive rocks, including agglomerates, near Greenore, prove that

those rocks are much older than those with which they are associated. This unconformability, however, does not appear to me to be of any importance, as such is there to be expected; because agglomerates usually form protrusions in the rocks with which they are associated;—witness the massive agglomerates in the Carboniferous rocks of Limerick, and elsewhere, and those in the Lower Old Red Sandstone (*Silurian*) of Cork, Kerry, and Roscommon; moreover, in the metamorphic rocks of Galway (*Cambro-Silurian and Cambrian*) there are masses more or less similar to that near Greenore; and to me it would appear absurd to say that the agglomerates in any of these places are more ancient than the associated rocks; as in each case they belong to the rocks with which they are associated.

In connexion with the Co. Wexford it may interest enterprising Laurentianists to suggest to them a new field for inquiry, which is the range of hills adjoining the mearing of the counties of Wicklow and Wexford, and extending from Croaghan Kinshellagh nearly to Kilcavan, as here there are many rocks of Laurentian types.

West Galway.

The rocks in this area I have worked most carefully; and it was not until after this examination was complete, and after I had carefully plotted sections across them, under the surveillance of Dr. Hull, that my opinion as to their age was matured. These sections were exhibited and explained* at the meeting of the British Association in Belfast (1874); and, if these are compared with the sections that have been published of the district, it will appear that the latter, although they are supposed to be taken from my work, are a mistaken misrepresentation of the facts as I have given them. Some of the most important incorrectnesses are, *first,* the rocks of the ophicalcite series are represented as being above the great quartzites of Bennabeola, while, in every case, they are below them; *second,* the rocks now said to be Laurentian—that is, the rocks south of the valley from Clifden to Oughterard—have a general dip southward, or away from the quartzites of Bennabeola. In some places they are inverted and reversed, as pointed out in the *Geological Survey Memoir,* while in other places there may be local northward dips due to the transverse faults; but the main dip is to the south, conformable with that

* By special permission of the Director-General.

of the underlying older quartzites, and not northward, as represented in these sections.*

In the Transactions of this Society, vol. i., pl. xxi., fig. 6, Dr. Hull gives a nearly north and south section across West Galway, in which the supposed Laurentian rocks are separated from the others by the great fault of the Clifden and Oughterard valley. This fault, as I have shown in the Government Survey Memoir, is a downthrow to the south. To meet Dr. Hull's idea, it would have to be a great downthrow to the north of over 5,300 feet. Even if Dr. Hull's general dip were correct, I do not understand how the rocks could get into the position represented as the result of a northern downthrow.

As has already been mentioned, Dr. King, before I examined the country, suggested that the quartzites, ophiolites, &c., of the Bennabeola and neighbouring hill groups were Cambrian or older; while, during the time of my examination, Sir R. I. Murchison, in a paper in the *Geological Magazine*, gave it as his opinion that the rocks of the Bennabeola mountains were of Laurentian age; which opinion he withdrew in a paper in the next number of that journal. During my explorations I searched diligently for an unconformability, or some indications of one, but found none; and my examination of the district, with a due and deliberate consideration of the facts detected, forced me to come to the conclusion that the rocks formed a continuous sequence, the oldest being of Cambrian and the youngest of Cambro-Silurian ages, with between them rocks representing the "Arenig rocks" of Wales, on the passage-beds between the Cambrians and the Cambro-Silurians; and from his preface to the Geological Survey Memoir (Exp. sheets 93, &c.), it appears that Professor A. C. Ramsay came to a somewhat similar conclusion during a short run through the country in the company of Dr. Hull.

As with the Tyrone rocks, so with these—the changes in opinion as to their supposed age have been sudden and unexplainable. In

* The maps and sections were carefully explained to Sir Richard Griffith, and left with him to examine, who, when returning them to me, expressed in a letter that he considered I had unravelled the geology of the district; and I find by a subsequent letter, dated Hendersyde Park, Kelso, N.B., Nov. 19, 1872, that Griffith was of the opinion that the rocks of the Forth mountains, Co. Wexford, the Cambrians of Wicklow, the rocks of the Twelve Pins, Connemara, and the rocks of Donegal, probably all belonged to one and the same geological period.

1874, when my work was finished, Dr. Hull appeared to agree with my opinions; but shortly afterwards when the memoir was published he insisted on saying that the result of my work was to prove the Lower Silurian age of all; yet afterwards, when he published his section, he suggested that some of them were probably Cambrians; while now he has again changed his mind, and declares that he "can have no hesitation in referring them" to the Laurentians.

In the Geological Survey Memoir, and also at page 21 of the "Geology of Ireland," I have shown that these Connemara rocks lie on an anticlinal curve, and that they range both northward and southward, in regular and similar sequences, from the lowest exposed strata in the western portion of the Bennabeola hills; as represented in the Diagram.

GENERAL SECTION OF THE CONNEMARA ANTICLINAL.

	North Side.	*South Side.*
	CAMBRO-SILURIAN.	
B 12.	*Croagh Patrick beds,* with inliers of serpentine, steatite, milestone, and hornblende-rock.	*Lettermullen beds,* with inliers of limestone, hornblende-rock, &c. (submetamorphic.)
B 11.	*Doolough beds,* fossiliferous in part. (Llandeilo), submetamorphic in part.	*Hornblendite and talcite series.*
	ARENIG.	
B 10.	*Great micalite series,* having in it, above, inliers of hornblende-rock, ophite, steatite, &c.	*Great micalite series,* having in it above, inliers of hornblende-rock, ophite, steatite, &c.
B 9.	*Lettermore quartzite series.*	*Small quartzite series.*
	CAMBRIAN.	
B 8.	*Kylemore series,* containing many limestones.	*Ballynahinch series,* containing many limestones.
B 7.	*Middle micalite series.*	*Middle micalite series.*
B 6.	*Great quartzite series.*	*Great quartzite series.*
B 5.	*Small micalite series.*	*Small micalite series.*
B 4.	*Ophiolite and dolomite series.*	*Ophiolite and dolomite series.*
B 3.	*Quartzitic micalite series.*	*Quartzitic micalite series.*
B 2.	*Streamstown limestone series.*	*Streamstown limestone series.*
B 1.	*Lower micalite series.*	*Lower micalite series.*

From the diagram and this general section, it will be seen that to the north and south of the curve the succession of the groups is similar, although the groups differ in thickness; while the sections across Bennabeola and the Corcogemore hills explain the present conditions of the groups; all the strata being more or less moved from their normal positions by the numerous faults that traverse the area in various directions.

From the section across Bennabeola, we learn that the great nearly E. and W. fault of the Clifden and Oughterard valley brings down the rocks of the *Middle micalite series* (B 7) against those of the *Quartzitic micalite series* (B 3), thus cutting out the intermediate groups, besides inverting the dip of the strata to the south of the fault. Here the order of the rocks is very much confused by the displacements due to this and other faults; the rocks of the *Great quartzite* and associated series being concealed in the country to the south of its line; but if we go further eastward to Lissoughter and to the Corcogemore hills, we find the *Ophiolite, Small micalite* and *Great quartzite series* (B 4, B 5, and B 6) lying on the ridge of the anticlinal curve, and dipping both to the northward and southward under the younger groups. The section to the southward is very complete, as only the *Small quartzite series* (B 9) and part of the *Ballynahinch series* (B 8) are concealed by the *Clifden and Oughterard fault*, while all the rocks dip regularly southward.

Elsewhere, as in the Geological Survey Memoir and the "Geology of Ireland," I have divided the metamorphic rocks into the *Gneiss series*, the *Schist series*, and the *Submetamorphic series*. If the county is traversed from Clifden southward to Ballyconneely, the rocks are found to belong to the "Schist series;" but the metamorphism probably decreases southward; because to the south-east and south, of a portion of the excessively metamorphosed rocks, in Lettermullen and Gorumna, the rocks of the *Lettermullen series* (B 12) are only submetamorphic.

If from the schists between the Clifden valley and Ballyconneely, we proceed eastward along their strike, they are found to graduate through gneiss into granite; this, however, does not take place suddenly, as before the main mass of the metamorphic

granite and granitoid gneiss is reached, outlying patches of these granites and gneiss occur in the country southward of Glendalough and Recess.

It will be also found that the further we proceed eastward, the more of the rocks of the older groups are absorbed into the granite and gneiss; so that in the country south and south-east of Oughterard, the intense metamorphism has also affected the rocks from those of series B 11 down to those of the Ballynahinch series (B 8). Going eastward from the Atlantic to the south portion of Lough Corrib, the graduation is along the strike of the strata; but it is transverse to it if we go south from Oughterard to Galway Bay.*

Let us now go from Bennabeola northward across the north series of the anticlinal, and we find that the rocks graduate from schists, through submetamorphic rocks, into unaltered fossiliferous rocks (*Doolough beds*), (B 11), at Rossroe, Mweelrea, and Toormakeady, the fossils being of Llandeilo type; while if the fossiliferous rocks of Mweelrea are followed eastward, they are found to have graduated into schists in the country between Doolough and Lough Mask.

In Mr. Mitchell Henry's hills between the Kylemore and Culfin valleys the hornblende-rock, ophites, &c., the upper members of the *Great micalite series* (B 10) are conspicuously developed. This is a very interesting district, as some of the rocks in it, which are undeniably above the quartzites of Bennabeola (B 6), are lithologically more allied to the Donegal rocks than any others in West Galway; and it appears to me if the similar rocks, to the south, in the *Great micalite series*, are to be classed as Laurentian that these also must be similarly classed; which would be absurd.

Furthermore, beginning to the N.W. at Ballinakill and going eastward and south-eastward along the rocks of the Kylemore Limestone series (B 8), past Kylemore and the Maum Turk

* Mr. E. T. Hardman has called my attention to conglomeritic rocks that contain blocks and pieces of grabbro, which he found in the supposed Laurentians of Sligo and Leitrim; and he suggests that these must be pieces of rocks belonging to an older group than that in which they are now found. I would also point out, as I have mentioned in the Geological Survey Memoirs and elsewhere, that there are very similar conglomeritic rocks in the co. Galway in the rocks now said to be Laurentians. These Galway conglomeritic rocks are in the *Hornblendite and talcite series* (B 11), while the contained pieces are similar to rocks in the *Great micalite series* (B 10) which was one of my reasons for supposing the latter rocks to be older than the former.

O 2

hills to Oughterard, and thence westward to Clifden, we find the same series of strata around three sides of the *Great quartzite series* (B 6) of the Connemara hills; while outside these rocks, except to the south and south-east of Oughterard, where they are changed into gneiss or granite, we find the rocks of the *Great micalite* (B 10) and the *Hornblendite* (B 11) *series*; which appears to me also strong evidence against the rocks south of the Clifden and Oughterard valley being of Laurentian age.

In conclusion, I would specially point out that I have never asserted that there are no Laurentian rocks in Donegal; but I do assert *that conclusive proofs of their existence therein have still to be produced.* Years ago Dr. Haughton classed the granitic rocks of Donegal and Galway together, and now Dr. Hull states he has no hesitation in referring both to the same geological time, while Dr. Sterry Hunt has stated that certain altered Palæozoic rocks, later than Laurentian, cannot be distinguished from some of the Donegal rocks. If therefore these Donegal rocks are lithologically similar to those of Galway and to the Cambro-Silurians of America, one of the arguments in favour of their being Laurentians falls to the ground.

Of the area near Belmullett, N.W. Mayo, I have only a limited knowledge, having been there only for a few days; but on seeing the rocks I was at once struck with the great difference between them and those with which they were associated, and, as I have already mentioned in a previous communication to the Society, with their similarity in many peculiarities to the granitic rocks of Carnsore, county Wexford; for which reason I suggested that they were probably of Cambrian age.* In regard to the other areas of supposed Laurentians, I believe that elsewhere I have given better reasons for supposing them to be of Cambrian age† than any which have since been put forward in support of their being Laurentians; it is therefore unnecessary to repeat them.

I have observed that some, at least, of the Laurentianists, when it suits them, lay great stress on the lithological characters of rock at great distances from one another; while, if these characters do not support their theory, they get rid of the difficulty by saying that the change is not greater than what

* Scientific Proceedings of the Royal Dublin Society. *Antea* page 148.

† "Supposed Upper Cambrian rocks." Royal Irish Academy Proceedings, 2nd Series, Vol. iii. (Science), page 348.

might be expected on account of the distance between the places. As elsewhere, so I would now again point out that the Laurentianists pin their faith too much on lithological characters; while they nearly altogether neglect petrological or stratigraphical evidence; and it would appear to me that if they go on as they have began, we shall have, before long, every metamorphic region, no matter what the age of its strata, dotted over with their Laurentian rocks.

Note in Press.

In a paper on the "Geological age of the Taconic system," read before the Geological Society of London, Professor J. D. Dana, in opposition to the view that the geological age of strata can be inferred from their mineral characters, pointed out what remarkably different rocks have been produced by the metamorphism, in different degrees, of the strata of Taconic range.—*Geol. Mag., New Series, Decade* ii., *Vol.* ix., *page* 282 (June, 1882).

XVIII.—ON THE METAMORPHIC ROCKS OF COS. SLIGO AND LEITRIM, AND THE ENCLOSED MINERALS WITH ANALYSIS OF SERPENTINE, &c. By EDWARD T. HARDMAN, F.C.S., WITH MICROSCOPICAL NOTES ON THE SERPENTINE. By PROFESSOR HULL, LL.D., F.R.S.

[Read June 19th, 1882.]

PART I.

The portion of the metamorphic rocks referred to in this paper includes the N.E. extension of the Ox Mountains, from Colooney to the north of Manorhamilton, a considerable part of which forms the southern shore of Lough Gill.

Besides this principal mass there is an inlying portion protruding through the carboniferous rocks of Rosses Point to the north-west of the principal mountain line and 9 or 10 miles distant from it. The general characters of both agree however in all essential respects.

1. *Ox Mountain Range.*—These rocks form a ridge some 3 to 4 miles wide, showing a series of irregular peaks semi-rounded by glaciation. The principal heights are about 900 feet, although Benbo Mountain rises to an elevation of 1,365 feet. The other chief elevations are Benbo Hill 849, Rockwood (or Slish Mountain) 967, and Slieve Daeane 900. South of Lough Gill, Union Wood 440; and Carrownageeragh to the west of Colooney. The last being 602 feet.

The north-west boundary of these rocks is very precipitous in places, especially in the district between Ballisadare and Slishwood, where there is a cliff boundary about 100 feet high. This marks a line of fault which has been traced from near Ballisadare to Saddle Hill, county Leitrim, a distance of over 20 miles.

On the south the rocks, although rugged, are not very precipitous, and while it is probable that a fault occurs on this side also, it is not so apparent as on the other side of the range, in both cases bringing down the carboniferous rocks, on the north side (the downthrow being the greatest), the Upper Carboniferous Limestone, and on the south the Lower Limestone. See section, Figure 1 (on page opposite).

General Character of the Rocks.—In this district there is not always to be drawn a hard and fast line between the different varieties of the few metamorphic rocks which occur in it. These consist indeed of but four classes, viz.: granitoid gneiss, gneiss proper, mica schist, and quartzite. But in few cases is it possible to determine a boundary between any two of them. Thus the first may be seen to pass into the second, and so on.

A good example of this is to be seen in the section west of Slieve Daeane, where in the space of some 400 yards, there are numerous transitions of gneiss, schist, and quartzite into each other, without any apparent rule or order in the process, all apparently changing indifferently one into the other.

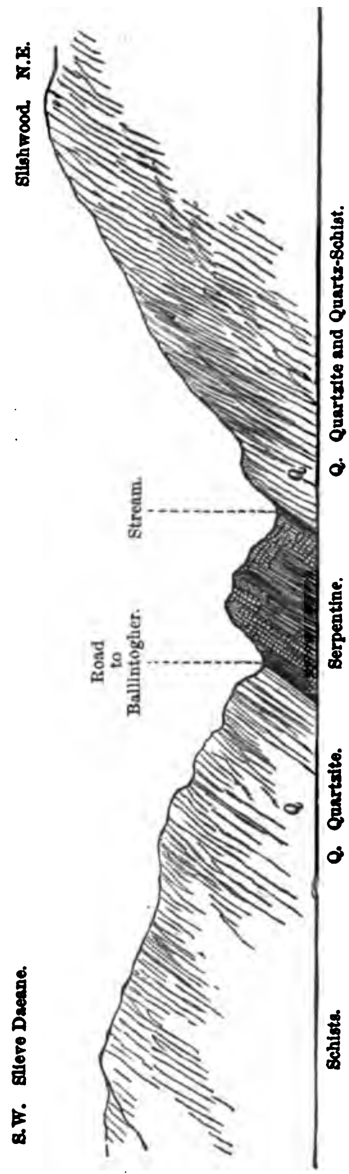
On the whole the gneiss largely predominates, the quartzites come next, and the mica schist last of all.

Of these the gneiss is the most interesting, from a mineralogical point of view; containing, as it does, a great variety of large crystals of quartz, biotite, muscovite, tourmaline, felspar (both red and white orthoclase), hornblende, and olivine, and very often garnets, but in minute crystals.

It is also remarkable for a curious band of conglomerate which occurs north and south of Ballydawley Lake, near Union Wood. This rock is a coarse granitoid gneiss, containing lenticular blocks and rounded pebbles of diorite or hornblendic rock weathering out on the surface.

South of the lake, and nearly a mile from the first exposure, the same conglomerate appears, although shifted to the east by a fault. Here some of the boulders are 2 feet long, and 8 to 10 inches wide. The whole visible thickness of this bed, or series of beds, is about 200 feet, and it is an important find in one way, namely, that whether we consider the diorite pebbles to be altered or not from the parent rock, their presence in the gneissose beds proves the existence of an older rock prior to even the formation of those beds.

Serpentines.—Three well-marked bands of serpentine occur in these rocks. The chief one appears at Slishwood, and occupies the valley running nearly south from Bunowen Bay, Lough Gill, for nearly two miles, and has an average width of about 500 feet. It will be fully described further on. Its chief peculiarity is that it is highly magnetic.



G. 1.—Section across Slishwood and part of Slieve Daeane, showing position of Serpentine rock.

Next comes a band near Drumahaire (three miles N.E.), trending nearly east and west. It is probably 300 feet thick at least; but its extension along the line of strike is not ascertainable, owing to thick coverings of drift and bog.

Finally, close to Shanavan's Bridge, near Manorhamilton, there is a well-defined band of serpentine, trending nearly N.E. and S.W. It is, however, cut off by two faults, and can only extend about half a mile in each direction. This contains mica and chlorite.

Neither of these last serpentines are perceptibly magnetic, although not generally different in external appearance from the first. They also want the numerous bands of tremolite which distinguish the former.—(See Part III., p. 183.)

Rosse's Point Section.—In this region a triangular boss of metamorphic rock occurs, which has not yet been noted on any map, or in any other publication. It is about 2½ miles long, and about a mile at its greatest width. It is difficult to account for its appearance here, within the limestone district, unless we suppose it to have been upheaved by more than one fault. One to the north is sufficiently apparent, but the other junctions are hidden by drift.

The rocks in this district are of a similar character to those of the Ox Mountains, and consist of coarse gneiss, often hornblendie, and mica schist. Quartzites are absent. The gneiss contains in places small garnets.

List of Minerals, and Remarks thereon.

Quartz.—Disseminated throughout; sometimes occurs in large ill-defined crystalline masses.

Felspar.—Chiefly, if not altogether orthoclase, both white and pink; the latter very common; both often in extremely large crystals, as near Colooney, also in the rock north of Ballintogher.

Mica.—Muscovite and biotite are found very usually in the same rock, often in very large crystals. Some specimens (muscovite) obtained near Ballintogher afforded flakes more than 1½ inches in diameter.

Tourmaline is not unfrequently met with in small crystals. Near Colooney a magnificent mass occurs, consisting of large crystals, radiating in a star-like form, about two feet in diameter. The crystals, which have a tapering form, are some-

times nearly one inch in diameter at the base. They are enclosed in milk-white quartz, which retains a perfect cast of the form and striation of the crystal, and must, therefore, have been deposited later. The contrast presents a very beautiful appearance. Associated with these is pink felspar in very large crystals.

Olivine is disseminated in small crystals in many places.

Garnets are found near Rosse's Point, and in the coarse gneiss west of Carrigeencor Lake. They are very small.

Copper Minerals.—Chalcopyrite occurs in quartzite near Shanavan's Bridge, in an old copper working.

Azurite.—Very beautiful specimens were obtained at the same locality.

Malachite is found at the same locality associated with the other copper minerals. It also occurs in a decomposed vein in quartzose schist, associated with galena, one mile N.E. of Manorhamilton.

Galena in small quantity in last two localities.

Cobalt.—In the last locality some specimens, apparently containing cobalt, were obtained.

Pyrites.—This is found in small specks throughout. It is associated with the copper minerals at the mine at Shanavan's Bridge.

GEOLOGICAL AGE OF THE METAMORPHIC ROCKS.

On this point we have as yet no definite information. That they are extremely old we cannot but admit. Unfortunately, in the Sligo district the links between the carboniferous and older rocks are wanting, and it is only possible to judge from analogy, and resemblance to other rocks of known age. Accordingly, they have been ascribed to a very early age by most geologists—amongst others, Mr. Kinahan places them in the Cambro-Silurian,* while Professor Hull traces their origin still further back, to the Laurentian system †; and there is indeed no reason to deny that they may even be of that vast age.

The Section will demonstrate the difficulty of determining their age on stratigraphical grounds alone.

* Geology of Ireland, p. 216.

† "On the Laurentian Rocks of Donegal, &c." Scien. Trans. Roy. Dub. Soc. Vol. I. Ser. II., p. 252.

Part II.

The highly Magnetic Nickeliferous Serpentine, from Slishwood, near Sligo.

This rock is of a rare character, and I believe that up to the present no serpentine containing magnetite in quantity has been recorded as having been noticed in Ireland. So far as I am aware the only instances given of such a rock are those cases mentioned by Bischof, as occurring at the Heidelberg, near Darmstadt; and at the Auschkul Lake.* The description of the first of these resembles in the closest manner that of the Sligo rock, as will be seen hereafter.

The serpentine at Sligo forms a well-defined and very regular band amongst the metamorphic rocks on the southern shore of Lough Gill, and extends from Bunowen Bay along by Slishwood, in a south-easterly direction for about a mile and a half, when the Carboniferous Limestone supervenes, and cuts it off. It has a thickness of about 500 feet, being, as observed by Professor Hull, the most extensive and regular band of serpentine in Ireland. The section on page 359 will explain the manner in which it occurs.

Physical Characteristics.—The rock is apparently an ordinary common serpentine—dark coloured, compact, and somewhat hard. The bedding is very distinct, and along the planes of bedding, well-defined bands may be seen, which, at first sight, appear to be bands of grit, but on closer inspection prove to be bands of a hydrous silicate in all essential points resembling serpentine, but containing a larger quantity of water. In all parts of the rock magnetite occurs, but chiefly on the western side of the band. To the eastwards the rock is more homogeneous, and it was when examining the tiny black particles which appear in this part of the rock, that I became aware of the magnetic character of it. In the most compact specimen of this rock minute grains of black matter will be seen, and on powdering a portion, and running a magnet through it, a quantity of magnetite can be extracted. Tracing the rock to the westwards, this mineral becomes more and more abundant, and close to the western boundary occurs in very large quantity indeed, and portions of the rock possess all the characters of natural magnets. They attract and repel the magnetic needle, and have distinct polarity.

* See chapter on Serpentine. Chem. Geol., Bischof.

Some specimens now exhibited have this property in a very marked way.

It is towards this side also that the fibrous mineral most predominates, and this mineral also contains a very large quantity of the magnetite, which is disposed in lines along the planes of lamination, and, as in the case of the other portions of the rock, *almost parallel to the magnetic meridian.*

Polarity of the Rock.—As to the precise direction of the poles of the rock, I am not quite confident, but I believe them to lie for the most part very nearly north and south—the N. pole of course to north. There is a difficulty in obtaining specimens out of the mass, in such a way as certainly to identify their original position, the rock being very splintery; but the majority of my observations leads me to the above opinion. In at least one case, however, the poles were inclined with the dip of the rock. The north pole being lowest, and towards the west, the south being uppermost.

Effects on Surveying Instruments.—As may be supposed, the rock has a very decided effect on the magnetic needle, and I made some few experiments to test the amount of this. Taking a point about the centre of the rock, I made a traverse on each side for about 300 yards, and I found a difference of 5° in the readings of the compass between the points on each side. It was, however, very difficult to be certain as to the North point, and I did not altogether rely on these observations. In order to make sure, the following plan was adopted:—A tree, nearly due west of one on the rock was chosen, and about 1000 feet distant. The observation with the prismatic compass was as follows:—

Reading from distant tree to that on rock -		90° 30′
„ „ tree on rock to above -	-	264° 00′
The correct reading should be - -	-	269° 30′
		264° 00′
Therefore disturbance of needle -	=	5° 30 to E
The direction of a portion of the road was taken (close to rock) - -	=	177° 00
Direction as obtained from 6-inch map	=	175° 00
Deflection - -	-	2° 00.

The prismatic compass I used was the reverse of delicate, and not much affected by small portions of the most magnetic specimens.

I should mention that this effect on the magnet would appear to have been observed before, for when I was examining the rock an intelligent old countryman came up and spoke thus—I give his own words, as they are brief and pithy: "That's a mighty quare rock, sir. They do say that it never could be surveyed by mortal man. Them that tried it always found their instruments went wrong, and they could make no hand of it at all, at all."

Chemical Composition.—This is nearly that of most rock serpentines, except that it is highly aluminous even when it is perfectly compact and has no visible traces of tremolite or asbestus, in which alumina might be supposed most likely to occur. Indeed an analysis is not required to prove this point as the compact rock when breathed upon gives the peculiar earthy odour of aluminous rocks; but the chief points worthy of remark about the rock are the presence of magnetite and of nickel. As to the latter it has not often been found in serpentine. There are a few instances mentioned by Dana. It has been recorded as occurring in the Black Serpentine of the Lizard by Bonney and Huddleston, and I myself have noticed it in that of Croagh Patrick, county Mayo, a rock which closely resembles the Sligo one. It very likely takes the place of some of the magnesium. Stromeyer has obtained from 0·22 to 0·45 per cent. Ni O in Serpentine of Roraas, Tundal, and Saxony; Lynchnell and Sterry Hunt 2·24 per cent., in the serpentine of some parts of America, of Cornwall, of Banffshire, of the Vosges, France.

I have not had time to make a complete series of analyses of this very interesting rock, but the following will give a fair idea of its general character.

ANALYSIS I.

Compact Serpentine. No Magnetite apparent on casual Observation.

$Si\,O_2$	38·13
$Al_2\,O_3$	5·5
$Fe_2\,O_3$	1·30
$Fe\,O$,	6·00
$Mn\,O$,	0·95
$Ni\,O$,	1·25
$Ca\,O$,	1·00
$Mg\,O$,	30·32
Water,	12·80
Magnetite $Fe_3\,O_4$	4·0
	99·75

ANALYSIS II.

Containing much Magnetite in Bands.

SiO_2,	34·06
Al_2O_3,	6·20
[Fe_2O_3, *	0·35] ?(doubtful.)
FeO,	2·00
CaO,	0·85
MgO,	31·69
Magnetite,	12·39
Water,	12·46
	99·65

ANALYSIS III.

Another portion of same Specimen.

This gave magnetite 14·35 per cent., but does not materially affect a prismatic compass. It, however, strongly affects a delicate needle.

The de-magnetised portion had the following composition:—

SiO_2,	39·20
Al_2O_3, Fe_2O_3, FeO, MnO,	11·80
NiO,	1·00
CaO,	1·00
MgO,†	34·48
Water,	13·25
	100·73

NOTE.—The general relation of the silica, magnesia and water in this analysis closely resembles that given by Dr. Haughton of the red serpentine of Cornwall. (Phil. Mag., vol. 10, p. 253, and Jukes and Gerkin, p. 142.

I have not estimated the proportion of peroxide of iron, or protoxide of iron and manganese in this specimen. But I may mention that the amount of peroxide is very small, and the greater bulk of the united weight is due to the alumina. It contains 3·75 per cent. of protoxide of iron.

Besides the above I have made several partial analysis of other portions of the rock, but they possess no particular interest except that they show the rock to be throughout of very similar composition, invariably containing alumina and magnetite, with nickel sometimes reaching up to 2·5 per cent.

* In this analysis there is some uncertainty as to the presence of Fe_2O_3.

† Other specimens of the rock gave 35·00 and 36·45 per cent., magnesium oxide.

It is of course not a normal serpentine insomuch as the proportions are not those of the *mineral*, but in every respect answers fairly to the character of *serpentine rock*. At any rate the term aluminous magnetitic serpentine would be a correct name for it.*

In no case have I obtained a specimen of it *without* magnetite, even the compact specimens contain a little of this, and it occurs in all quantities from 2 per cent. up to 15 per cent. nearly. I have not tested specimens containing less or more, but, I have no doubt they may exist.

If the rock is finely powdered and a magnet passed through it the magnetite forms a brush on the poles; a quantity of it can be taken out thus.

I applied this method for the determination of the per-centage, but I find that Bischof, who has a very aggravating way of anticipating geological chemists, used the same method for the extraction of the magnetite from the serpentine of the Heidelberg. He mentions that as much as 13·6 per cent. was extracted in this way, but that the actual proportion must have been smaller as it would be difficult to eliminate it completely from the rock.

The Sligo rock therefore contains the highest recorded percentage.

In order to be certain that the magnetite was entirely eliminated I subjected the powder to frequent levigation and elutriation, sifting frequently with the magnet, so that I do not believe that 0·10 per cent. of rock remained attached to the mineral when finally weighed.

In conclusion I would briefly remark on the bearing of the presence of this mineral on the origin of this serpentine rock.

I need hardly refer to the fact that serpentine is never found unassociated with metamorphic or igneous rocks. Yet there are some who hold that serpentine may be deposited amongst sedimentary rocks as a wholly aqueous deposit. It will be in memory of those present that Dr. Sterry Hunt in a very able paper read at the last Dublin meeting of the British Association strongly upheld this view.

Now the Sligo serpentine would at first sight appear to agree with this view. It is most clearly a stratified rock, well and very

* It is possible indeed that the rock should be called eklogite serpentine if it could be a product of alteration of augitic rocks. This however is improbable.

regularly bedded, and perfectly well defined with regard to the quartzose rocks on each side. There is no merging of one into the other.

But, on the other hand, how can we account for the magnetite? Supposing we admitted the sedimentary character of the rock. I believe there is no case on record of magnetite being found in rocks other than those which have been metamorphosed, or which are of known igneous origin, and in which it is notably of common occurrence. It is also easily produced by the chemist under conditions of intense heat; but no one has yet succeeded in obtaining it from chemical decomposition in the cold. It may, therefore, be taken for granted that at the time the magnetite was developed in the serpentine that rock must have been subjected to a very intense heat—doubtless a moist heat under great pressure. The rock must, therefore, have been altered since its deposition, and therefore could not have been—what it is now—serpentine originally.

The present case can be easily accounted for by the alteration of ordinary magnesian limestone and shales. This great band of serpentine was perhaps originally a bed of magnesian limestone intercalated between shales and sandstone rocks. Carbonate of lime was gradually eliminated, and replaced by silicate of alumina and magnesium from the accompanying shales, and the oxides of iron under the influence of intense heat and super-heated steam were in part converted into magnetite.

This is partially confirmed in the present instance by the fact that at the basal junction of the rock with the quartzite the serpentine merges into what has all the appearance of altered carboniferous limestone shale.

The probability of such a conversion is, of course, beyond all question. Serpentine is of common occurrence amongst altered limestone, as is mentioned by Bischof and others; and I have myself noticed the actual passage of a magnesian limestone into serpentine near Tramore, county Waterford, where the silurian rocks are greatly invaded by igneous and trap rocks.

Chrysolite and Tremolite, or Asbestus.—I should mention that the Sligo serpentine contains numerous bands of a fibrous mineral which answers to many of the characteristics of chrysolite, but that it contains a very large per-centage of water—as much

as 17 per cent., and encloses quantities of magnetite. There are also abundant bands of a mineral which closely resembles tremolite in some cases, or asbestus in others. Besides these there is in joints and fissures abundance of a green mineral whose composition approaches that of true serpentine.*

Part III.

Microscopical Notes on the Appearances of the Serpentine, with Asbestiform Tremolite, from Sligo.

Four specimens of this remarkable material were sent by Mr. Hardman to me for examination, with the following results :—

No. 1. Dense dark-green serpentine, with a narrow band of nearly white fibrous, silky tremolite.†

Microscope.—A thin section transverse to the band of tremolite is well seen with an one-inch objective. The serpentinous mass appears as a light yellowish-green amorphous material, with reticulated or net-like divisions, through which are dispersed formless groups of magnetite grains. The tremolite appears as a band traversing the mass, with fibrous structure, the hair-like prisms being perpendicular to the walls. It is divided into two portions by a central band of amorphous colourless matter, and it would appear as if the tremolite had crystalised out from the opposite walls of the fissure on either side, leaving a partially unfilled space in the centre, as in the case of some mineral veins. A few translucent spaces occur amongst the mass of the serpentine filled with a colourless material with a wavy fibrous structure, which probably consists also of tremolite.

Polariscope.—With this the effect is striking. With crossed nicols the serpentine presents a spangled field of rich saphire or indigo blue, of varying depths, and broken up into individual

* Analysis IV.—Green mineral, like chlorite, but with composition of serpentine—

SiO_2	FeO	Al_2O_3	Fe_2O_3	MgO	Water.	Total.
42·40	2·107	4·80	2·63	32·695	14·69	99·322.

† In the following description I have called the fibrous mineral of these sections "tremolite," in deference to Mr. Hardman's determination; but it does not seem to answer very well in its optical properties to the mineral of this name as described by Rosenbusch. (See *Mickros. Physiographie*, s. 307).

grains of irregular form. With parallel nicols the same mineral has a slightly yellowish tint. With this vivid polarization it may be inferred that the mass is in a molecularly crystalline condition.

On the other hand, the tremolite with crossed nicols exhibited a deep blue tint, shading off into purple, and finally into golden yellow, according to the varying thickness of the section. With parallel nicols the colours were sulphur yellow, passing into light blue; the fibrous structure is very distinct.

No. 2. Rock formed of alternating dark-green bands of serpentine, and nearly black material.

Microscope.—The appearance is very peculiar. The field shows layers of light greenish-yellow serpentine, with net-like structure, similar to that in the former specimen, but alternating with black bands of magnetite bounded by jagged edges. These bands are not continuous, but broken, irregular, and variable in breadth, sometimes represented by mere specks. There is also a large irregular mass of magnetite grains enclosed in the serpentine in one part of the field.

Sometimes along the edges of the bands the magnetite seems to be intimately associated with tremolite, which also occurs in thin bands, being parallel to, or alternating with, the long fibrous prisms. This is shown with a high power (one-fifth objective), where, in one instance, the replacement of the tremolite fibres by little black rods of magnetite dust is very clearly shown. The proportion of magnetite in this specimen is unusually large.

Polariscope.—With polarized light this section presents a very beautiful appearance, owing to the surface being bespangled with varying depths of blue, brought out with crossed nicols. The effects are similar to those described in the case of specimen No. 1, and need not be repeated.

No. 3. Dark-green dense serpentine rock, traversed by approximately parallel bands of light-green silky tremolite (?)

Microscope.—In this instance the light yellowish-green serpentine, and colourless tremolite with fibrous structure, are intimately mixed throughout. The tremolite occurs in irregular —nearly parallel—bands, and the hair-like prisms are arranged

perpendicular to the walls of the inside bands; and, as the section has been cut transversely to these bands, the hair-like prisms cross the field from right to left. The serpentine has a reticulated structure.

Polariscope.—With crossed nicols the alternating bands of tremolite (?) and serpentine are clearly defined; the former showing the fibrous structure, and colours of yellow passing into purple; the latter, varying shades of indigo blue.

No. 4. Banded dark and light sap-green rock, with small flakes of mica in the folia.

Microscope.—Surface showing net-like spaces of light-yellow serpentine, mixed with clear colourless spaces, through which are distributed black strings of magnetite dust, sometimes intruding amongst the narrow meshes of the net-work, at other times forming long, slightly-bent bands, with jagged and branching sides. Tremolite is absent from this specimen.

With a high power (one-fifth objective and No. 2 eye-piece) the strings are seen to consist of magnetite dust, or very minute grains, which have apparently been extruded from the clear or coloured spaces during the process of metamorphism, and are now diffused through the minute cracks, and fissures, and joinings of the individual grains of serpentinous matter.

Polariscope.—The polarization in this case differs from that of the former specimens. With crossed nicols the serpentinous mineral often shows a wavy-banded structure of varying shades of indigo blue, like some varieties of agate. Throughout this mass are strings and branching veins of a mineral, evidently of newer formation, and polarizing with an opalescent play of colours where the prisms are crossed. I am uncertain as to its nature, but it may possibly be quartz.

XIX.—GLACIAL MORAINES ON MOUNT LEINSTER, COUNTIES WEXFORD AND CARLOW. By G. H. KINAHAN, M.R.I.A., &c. PLATES IV., V., AND VI.

(Read June 19th, 1882.)

In the coom at the head of Glen Clody, situated on the north-east side of Mount Leinster, there are remarkable traces of a glacier, to which I would direct the attention of the Society.

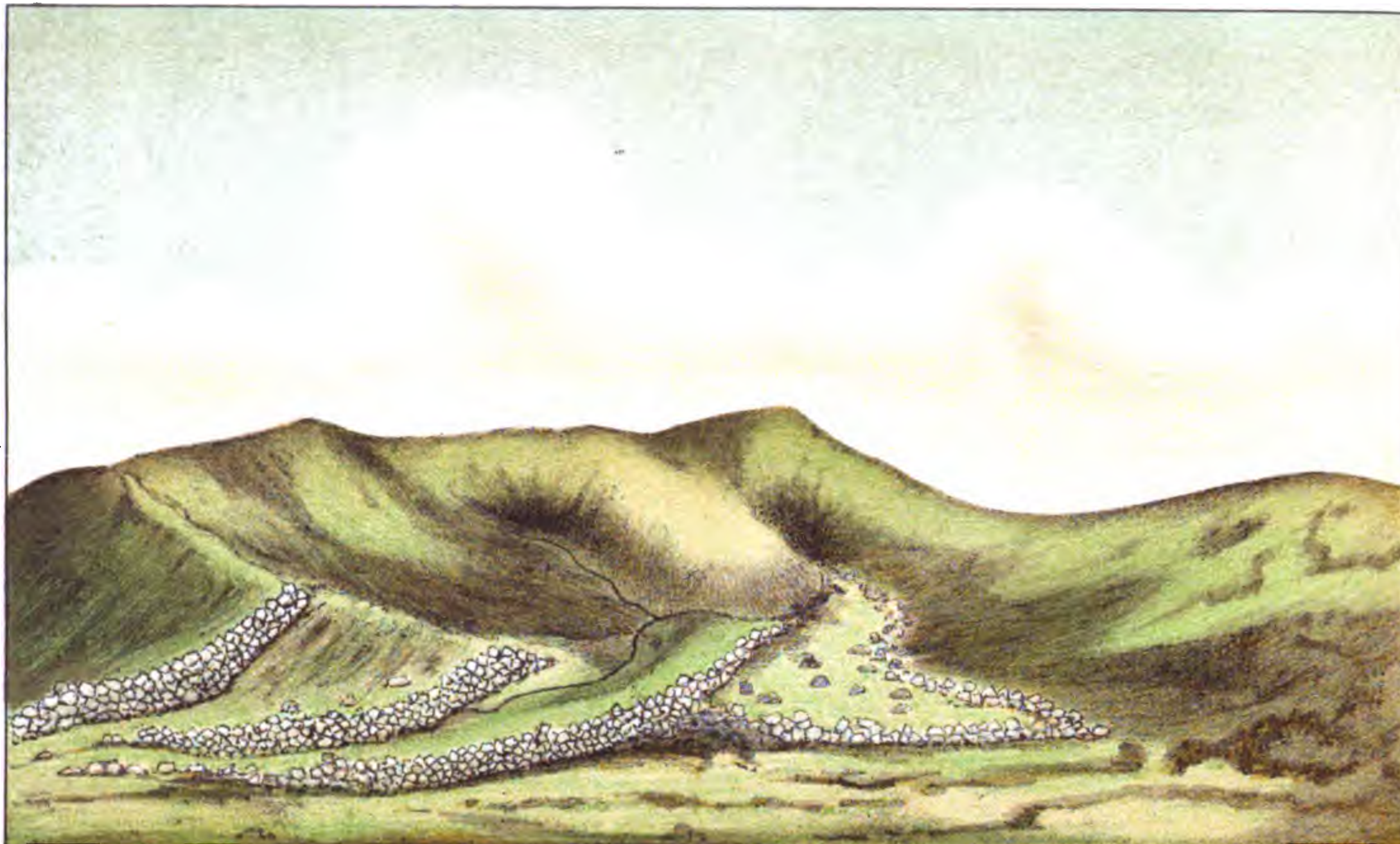
These traces consist of two long lines or walls of heaped-up granite blocks, which, from their character and the way in which they run, can be accounted for only by their having been deposited round the edges of a small glacier at two different stages of its development, at each of which it must have had very well-defined limits. The general appearance of the coom is represented by the sketch, Plate IV., while Plate V., shows the extent of the glacier at the two stages of its development; as indicated by the two lines of blocks, the blue representing the glacier at its last stage.

The south-east face of the north-west part of the inner moraine, Plate V. c., which is formed of huge blocks, is remarkably grand; being straight, nearly perpendicular, and from 20 to 40 feet high; it is represented in Plate VI.

The line of blocks outside the glacier, as represented in Plate V., indicates its original and greater extent.

The moraines in question are particularly interesting, for this reason that they are so different from the general type of corry moraines, of which there are so many in this country. They are almost entirely composed of large blocks without small detritus mingled with them; whereas ordinary corry moraines, though containing and carrying large blocks, have so much small debris mixed with these that they can act as dams to the tarns, or small lakes, which sometimes occupy the corry. I believe that there has been a peculiarity in the mode of their formation, apparently illustrated by what I have observed to take place at the present day in the same district.

As has been already pointed out in my "Geology of Ireland," page 311, in some winters large snow-drifts are formed in the cooms of the Lugnaquillia Mountains; and when the surfaces of these drifts become frozen over, all blocks that fall from the

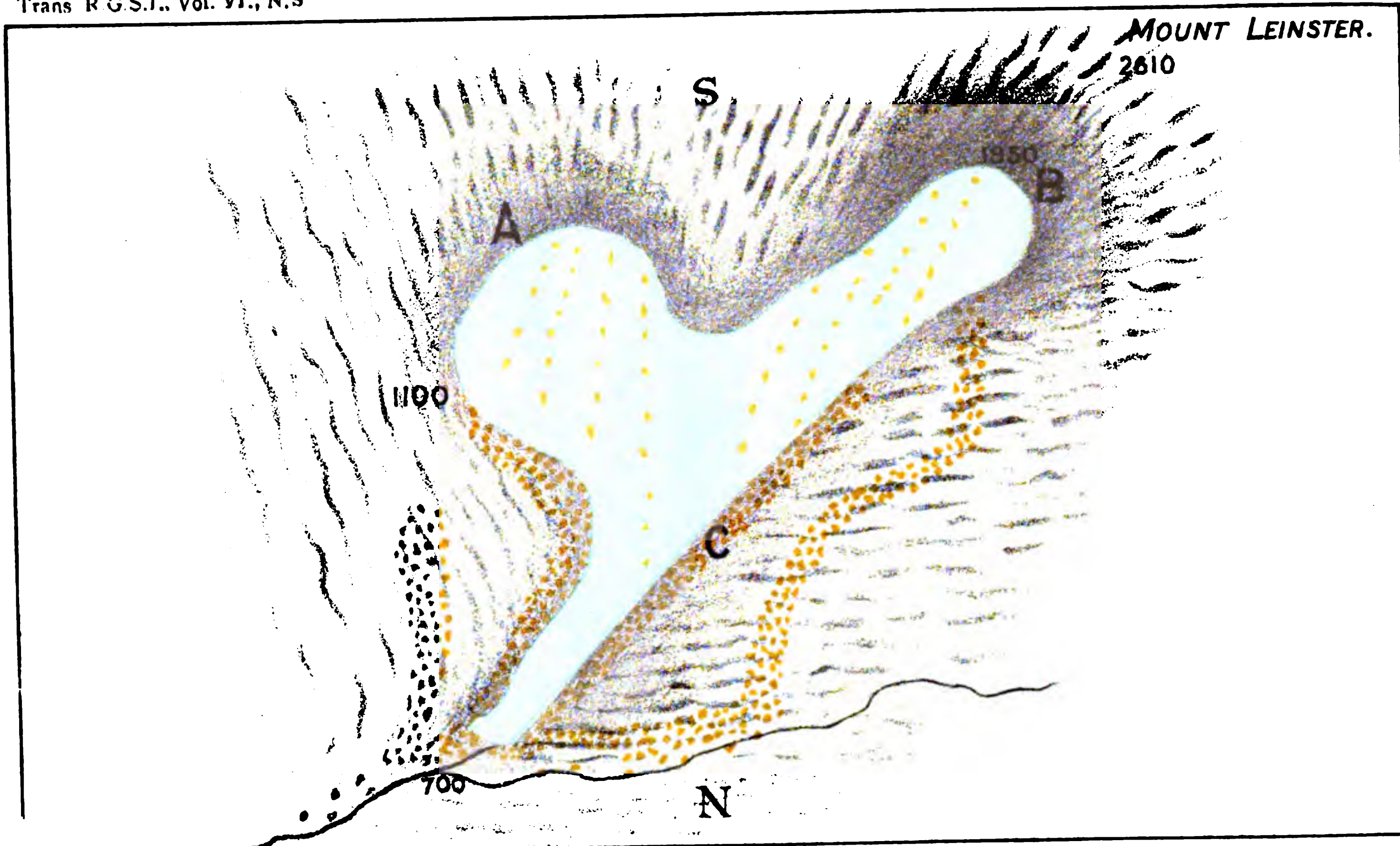


FORSTER & Cº LITH. DUBLIN.

Harriette A. Kinahan

CRAAN COOM TO THE N.E. OF MT. LEINSTER WITH ITS RECORDS OF A CORRY GLACIER.

AS SEEN FROM THE NORTH NORTH EAST



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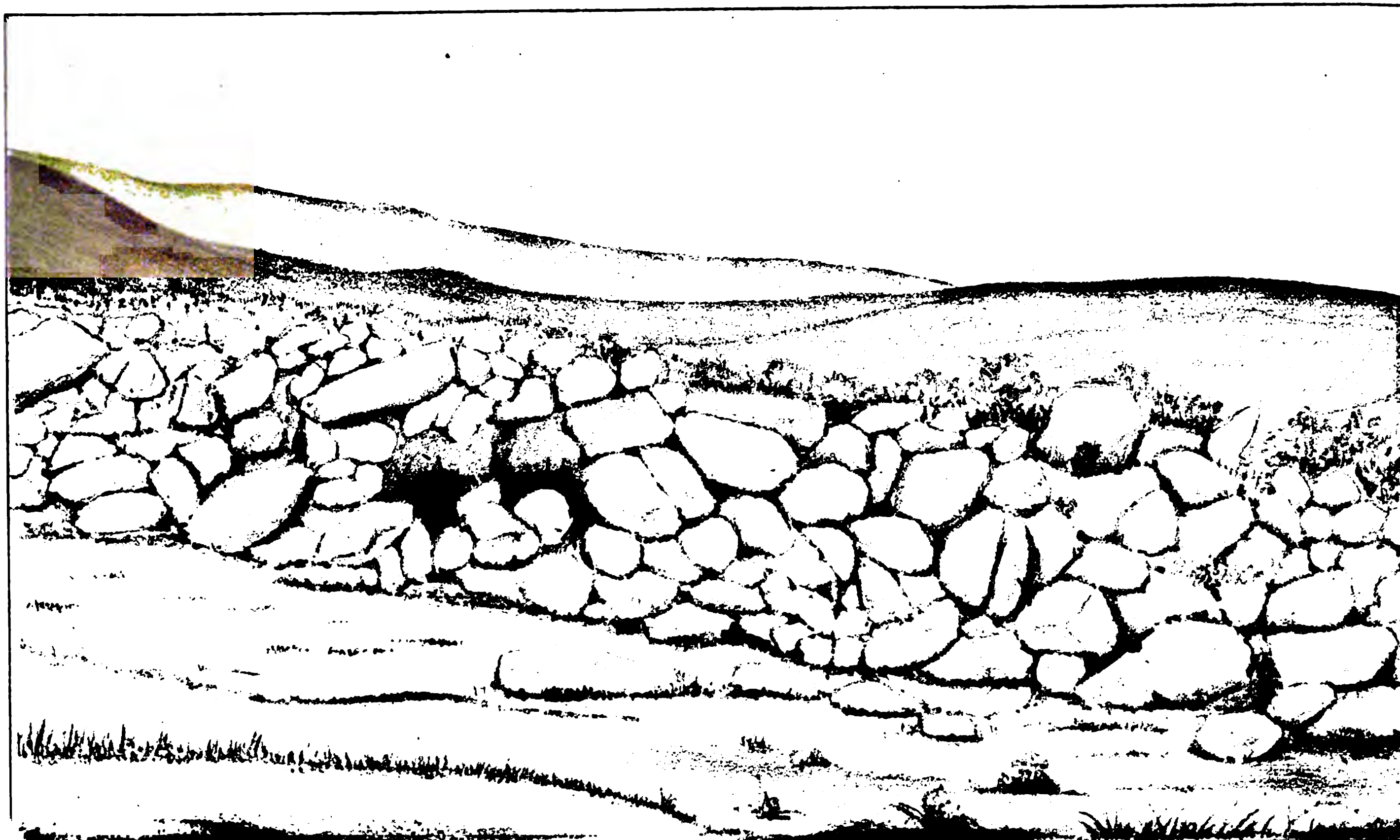
MAP OF THE ANCIENT CORRY GLACIER MT LEINSTER

Scale 3½ Inches to One Mile.



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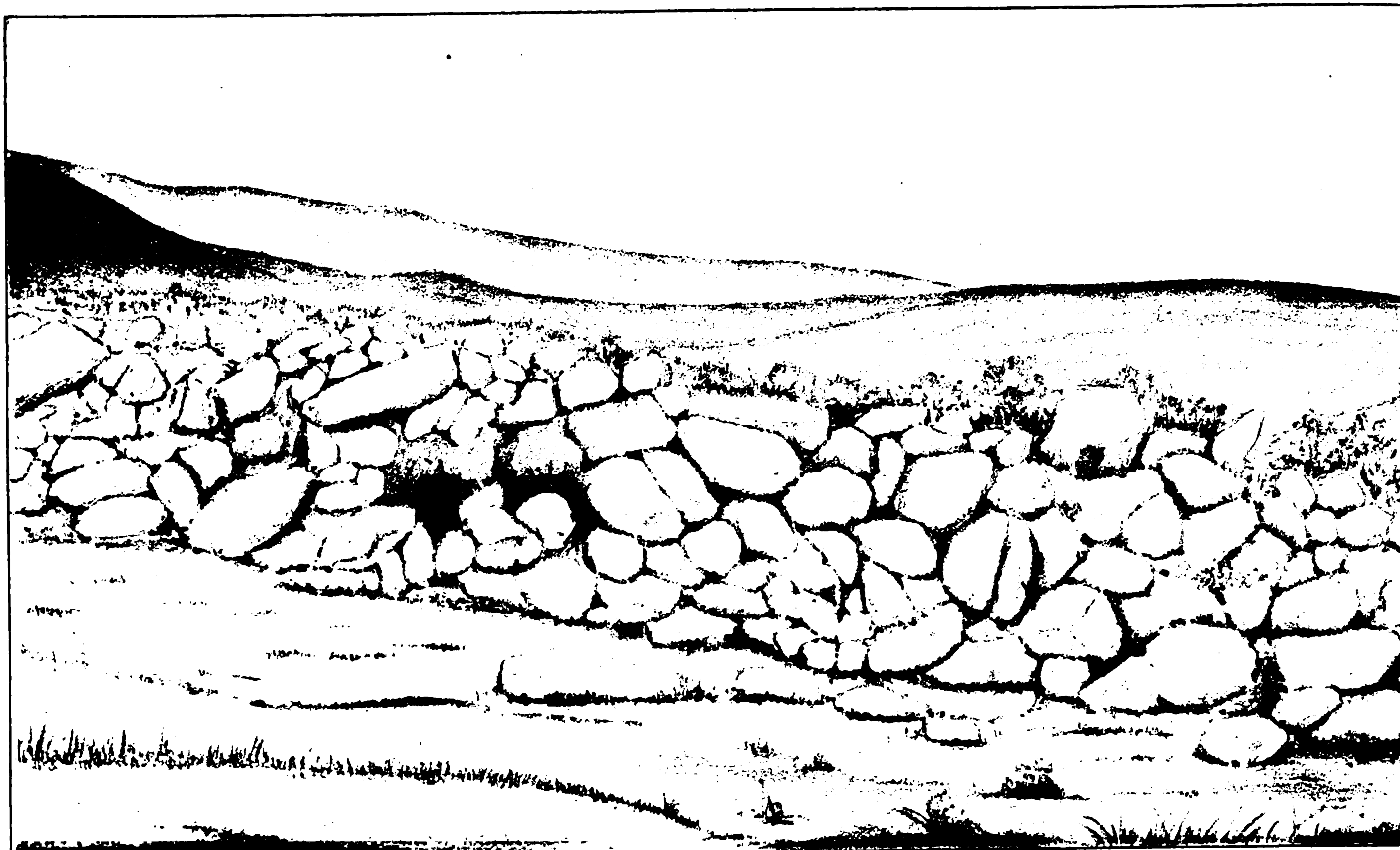
WALL FROM 20 TO 40 FEET HIGH ON THE N.W. OF THE SMALLER GLACIER, KILBRANNISH, CO. CARLOW.
AT C ON PLATE V
(WINTER.)



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Harriette A. Kinahan

WALL FROM 20 TO 40 FEET HIGH ON THE N.W. OF THE SMALLER GLACIER, KILBRANNISH, CO. CARLOW.
AT C ON PLATE V
(WINTER.)

adjoining cliffs on to them slide off, and form at their margins moraine-like accumulations; from which I would suggest that an operation somewhat similar, but on a much larger scale, took place in the Craan Coom on Mount Leinster, the blocks in the marginal heaps having partially slid down over the glacier, and been partially carried on the downward creeping mass of ice from the granite cliffs between A and B, Plate V., as indicated by the lines of blocks on the glacier, the marginal cliffs being more than 500 feet higher than the highest blocks, and over 1,000 feet above the lowest blocks; the space that was occupied by the glacier during the time of its smaller and later development, is comparatively free from blocks.

This coom gets the name "craan" from the numerous blocks in it. The N.W. coom of this mountain on its county Carlow side, in which there are no very striking indications of glacial action, is called Coolasnaghta, or the snow-corner.

In summer the lines of blocks are much concealed by the remarkably tall bracken growing about and among them they are therefore best seen in winter and early spring.

XX.—SOME NOTES ON THE GEOLOGY OF BRAY HEAD, WITH A GEOLOGICAL MAP AND SECTIONS. By GERRARD A. KINAHAN. Plate VII.

[Received August, 1882.]

While studying Geology, some few years ago, at the College of Science, Dublin, in order to familiarize myself with field Geology and practical work, I examined and mapped the more continuous sections of the Cambrian Rocks exposed on Bray Head. Since then I have examined and mapped the surface of other parts of the hill; and, as a geological map with some sections of this district may be of interest to the Society, I have been induced to lay it before them, especially as it will be more accessible in their Proceedings than the map of the Geological Survey. I have carefully compared them together, and find them to agree in the main. In this map, however, more breaks have been inserted; these cannot be taken as absolutely correct, but are what appeared to me, when on the ground, to be best calculated to explain the peculiarities, especially those of the quartz rocks.

As the rocks of this area have been the subject of many papers, and of much discussion,* I have refrained from giving a

* Such as:—"On the Rocks of Bray Head." Prof. Oldham, Journal Geo. Soc. Dublin, vol. iii., p. 60.

"Quartz Rocks of Bray Head and Howth." John Kelly, Esq., Journal Geo. Soc. Dublin, vol. v., p. 237.

"On the Structure of the North-Eastern part of Wicklow." By J. Beete Jukes and Andrew Wyley, Esqrs., Journal Geo. Soc. Dublin, vol. vi., p. 28.

"On Annelloid Tracks in Rocks of Bray Head." By J. R. Kinahan, M.B., Journal Geo. Soc. Dublin, vol. vii., p. 184.

"On the Organic Relations of the Cambrian Rocks of Bray (Co. Wicklow) and Howth (Co. Dublin), with Notices of the most remarkable Fossils." Professor Kinahan, Journal Geo. Soc. Dublin, vol. viii., p. 68.

"On Haughtonia, a new genus of Cambrian Fossils." By Professor J. R. Kinahan, M.D., F.L.S., Journal Geo. Soc. Dublin, vol. viii., p. 116.

"The Genus Oldhamia: its characters, probable affinities, modes of occurrence, and a description of the nature of the localities in which it occurs." By J. R. Kinahan. Trans. Royal Irish Academy (Science), vol. xxiii., p. 547.

"On a Trap Dyke at Bray Head, Co. Wicklow," by W. H. Stackpoole Westropp, M.R.I.A., Journal Royal Geo. Soc. Ireland, vol. i., p. 149.

"On the Lower Palæozoic Rocks of the South-East of Ireland and their Associated Igneous Rocks." By J. Beete Jukes, M.A., F.R.S., &c., &c., and Rev. Professor Haughton, M.A., F.T.C.D., F.R.S. Trans. Royal Irish Academy, vol. xxiii., p. 563.

detailed description of them. I have, however, with great diffidence, offered a few suggestions which may contribute towards a new explanation of some of the obscurities in the geological structure of the hill.

The rocks in this area, which are considered to be typical Irish Cambrians, consist of an immense thickness of green and purple grits and slates, with large masses of quartz rock. The slates and grits, although often twisted and folded, and sometimes even inverted, have a tolerably regular general strike nearly N.E. and S.W., with a general dip to the N.W. An observer crossing the summit of the hill at right angles to the strike of the strata, will meet with several masses of quartz rock which, although much broken up by small breaks, form more or less continuous bands, which seem to be conformable to the adjoining strata, and to form with them a continuous sequence. However, on examining the sections to the west and east (along the Delgany road and the railway), only two of these masses will be met with, and in these two there are such striking similarities, that very possibly they are portions of the same reef, which has been brought twice to the surface by extensive faulting.

In the lands of Bray Head House, on the northward slope of the hill, a large mass of quartz rock (A.) appears east of the House. This seems to be a bed that is conformable to the strata, the northern portion of which rests on the slope of the hill, with its upper surface exposed; towards the east, however, it curves sharply, and being doubled on itself, the edge of the bed only, appears a little to the south. Probably it is the same reef that is seen further to the S.W. (A.'), at the boundary between Bray Head and Ballynamuddagh.

Southward of these exposures is the reef (B.B') extending from the shore across the northern summit of the hill, in a slightly curved N.E. and S.W. broken line into Kilruddery demesne, east of the house. In the section exposed by the railway cutting this

"Memoirs Geo. Survey of Ireland," sheets 121 and 130. By J. Beete Jukes, M.A., F.G.S., and G. V. Du Noyer, M.R.I.A.

"Weaver's Geological Relations of the East of Ireland," Trans. Geo. Soc., series 1, vol. v.

"The Physical Geology of the neighbourhood of Dublin." By Rev. M. H. Close, F.G.S., Journal Royal Geo. Soc. Ireland, vol. v., p. 49.

"Physical Geology of Ireland," p. 8. By Edward Hull, LL.D., F.R.S.

"Manual of the Geology of Ireland," pp. 18, 35, 196. By G. Henry Kinahan, M.R.I.A.

quartz reef appears much thicker than it is in reality, as it is crossed by a break, by which it is doubled upon itself. Turning somewhat towards the south it becomes less compact on its under side; but the sequence south of this is indistinct, as the ground is much broken. On the north or upper side it is overlaid by grits and slates that are quite conformable to it. However, on looking up the slope of the hill, these appear to strike away from the quartz reef, which forms a very conspicuous feature right across the summit of the hill. South-east of this ridge there is a marked hollow across the hill, on the opposite side of which, in the lands of Ballynamuddagh, numerous small masses of quartz rock appear, which seem to represent one band of quartz rock much twisted and broken. This to the west disappears under the drift, while to the east it is cut off by a series of N.W. and S.E. breaks.

Still further south there is the second reef* (E.E′), forming a conspicuous ridge, and the highest point on the hill (793 feet). It extends from the Brandy Hole along the bounds of Ballynamuddagh and Rathdown Upper, towards Windgate. Like the main reef (B.B′) further north, it is much broken up by faults. In the section as seen on the shore it is overlaid by grits and slates having a reddish burnt appearance. The under surface of the reef has several peculiar rounded masses projecting from it, and rests on a comparatively soft, reddish sandy bed, under which are slates and hard quartzose grits. Some distance below these a bed of greenstone appears in the cliffs and railway cutting, and can be traced up the steep slope of the hill for some distance, but is lost under the drift towards the top, and could not be found further to the west.

The grits and slates on this southern slope are much twisted and folded, being repeated many times, as may be seen along the shore and railway cuttings, especially at the most southerly point of the head, beyond which, towards Greystones and towards the west, they pass under a deep covering of drift that extends for some distance up the slopes of the hill.

* The surfaces of these reefs are in many places well glaciated. The striæ being well preserved on the quartz rock, numerous other glacial evidences are to be found over the hill, such as transported blocks. The projecting headlands along the shore-line are also striated in some cases on highly-inclined or vertical faces.

It has been already stated that it seems very possible that the two principal reefs crossing Bray Head are disconnected portions of the same. This is only a surmise on which very little direct evidence can be produced Between the two reefs there is a great similarity, and the sequence of rocks in connexion with both presents a general similarity. However, below the Brandy Hole reef there is the greenstone dyke that is not to be found below the northern reef. This may be due to the dyke being a later intrusion, probably after the disconnexion had occurred, and this is supported by the fact that the dyke is not to be found under the western portion of the Brandy Hole reef.

At first sight there may appear to be a difficulty in detecting any line along which such a fault could cross the hill. But on closer examination, it appears very possible that the outcrop of this fault, which fault would dip south at a low angle, runs nearly parallel to that of the strata and along the hollow south of the more northerly reef, and instead of extending to the shore line at Bray Head, it turns south down the slope of the hill towards the Brandy Hole; this sudden flexure being caused by the breaking up of the strata along the numerous joints and breaks that cross their strike, and the subsequent removal of that portion lying above the plane of the main fault and east of some of the more marked of these breaks. The bearing of this main fault would be about E. and W., while it would be along it that the cave known as the Brandy Hole extended. On the westward slope of the hill, the sections and evidence in connexion with this fault are very obscure, as the glacial drift extends for some distance up the slopes of the hill, and above this there is in many places a thick covering of meteoric drift.

DESCRIPTION OF PLATE VII.

A.—The northern exposure of the upper quartz reef.

A′.—Supposed detached portion of the northern exposure of the upper quartz reef.

B B′.—Northern exposure of the lower quartz reef in places broken up and displaced by transverse faults.

C D E.—Supposed outcrop of the main fault (Brandy Hole fault), a down-throw to the south, which brings down the quartz reefs, thus causing them again to appear at the surface further to the southward.

C D.—Line of outcrop along the general strike of the strata, marked by a hollow filled with drift and peaty accumulations.

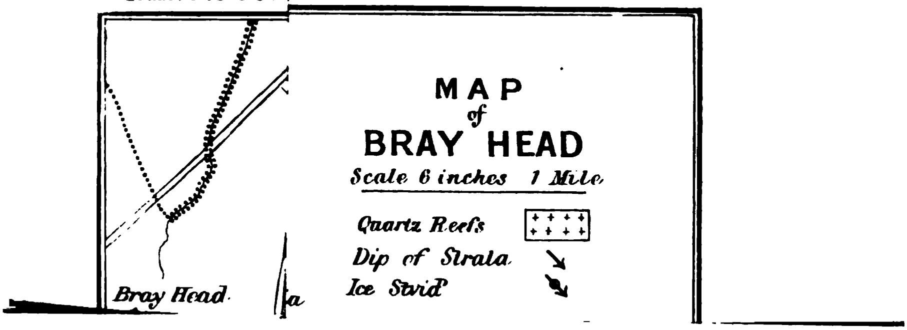
D E.—Line of outcrop along the principal breaks that cross the strata, marked by steep and abrupt ground south-west of this line.

E C.—Probable line of strike of the main fault.

D D′.—The southern exposure of the upper quartz reef A due to the southward down-throw of the main fault. The reef is much broken up and displaced by transverse faults.

D″.—Detached portions of the Ballynamuddagh quartz reef, whose relations to the reef D D′ are obscure.

E.—The southern exposure of the lower quartz reef B B′ due to the southerly down-throw of the main fault. The reef is broken and displaced by transverse faults.



[2] Proceedings, Asiatic Society of Bengal, January, 1877, p. 3.

[3] Records of the Geological Survey of India, vol. xiii., p. 161.

XXI.—ON SOME EFFECTS PRODUCED BY LANDSLIPS AND MOVEMENTS OF THE SOIL-CAP, AND THEIR RESEMBLANCE TO PHENOMENA WHICH ARE GENERALLY ATTRIBUTED TO OTHER AGENCIES. BY PROFESSOR V. BALL, M.A., F.R.S., F.G.S., Hon. Sec., Royal Geological Society of Ireland.

[Read, November 20, 1882.]

IN the year 1878 I published[1] a preliminary, and, of necessity, imperfect sketch of what, from the evidence then available, I believed to be the mode of origin of the series of lakes which occur at Naini Tal and its neighbourhood, in the North-west Himalayas.

The probable glacial origin of these unique Himalayan lakes had previously been suggested by Mr. H. F. Blanford;[2] but the tentative hypothesis put forward in my Paper was, that they were not true rock-basins, but were simply portions of river-eroded valleys, which had been more or less dammed up by the fall of *débris* from the slopes of the surrounding hills. So the matter was left, but not for very long, as, in 1880 my late colleague, Mr. Wm. Theobald,[3] having visited the lakes, pronounced them to be glacial.

By a singular coincidence, Mr. Theobald's Paper, and the first news of the great Naini Tal landslip, reached me at the same time when journeying to India in September, 1880. My first formed intention was, provided permission were obtained, to start for Naini Tal immediately on reaching Bombay, as I concluded that the phenomena exhibited by this landslip could not fail to throw light upon the disputed question as to the origin of the lake. I found, however, that a committee had been appointed by the Government to report upon the disaster, but that the services of a geologist were not considered necessary to take part in the deli-

[1] Records of the Geological Survey of India, vol. xi., p. 174.

[2] Proceedings, Asiatic Society of Bengal, January, 1877, p. 3.

[3] Records of the Geological Survey of India, vol. xiii., p. 161.

berations.[1] In due time this committee published a report which, while dealing with the lamentable destruction of life and property resulting from the landslip, did not throw much light on its cause. Fortunately, however, the appearances presented have been described by a geologist, Mr. R. D. Oldham,[2] who happened to be in the neighbourhood at the time. Besides giving a good description of the mode of operation of the agencies which culminate in such landslips, he adds some remarks of considerable interest which bear upon my view of the causes to which the lakes at Naini Tal and its neighbourhood owe their origin.

In spite of repeated friendly invitations by Mr. Theobald, that I should reply to his Paper, I deferred doing so while still any hope remained of my being able to make a further and more complete examination of the locality. And now, when all such hope is gone, I feel I am not in a position to add much to what has been already published; at the same time I have, since I visited Naini Tal, examined numerous undoubtedly glaciated lakes in England, Ireland, Scotland, and Switzerland, and I therefore feel increased confidence in suggesting what I believe to be the legitimate deductions to be drawn from the whole array of observed and recorded phenomena.

The illustrations and plans which I now exhibit will serve to convey an idea of the principal of these Himalayan lakes (Naini Tal) and its surroundings. For descriptive details of it and the others of the series I must refer to my original Paper. Here it will be sufficient, perhaps, to concentrate our attention on Naini Tal as typical, though some of the other lakes exhibit individual peculiarities indicating local modifications in form, which may possibly be connected with the irregular profiles impressed on the surface of the rocks at the time of their upheaval, and which are therefore less directly due to the effects of subaërial denudation.

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[1] By a strange coincidence, the author of an article on landslips, in *Nature*, dated September 30, and which was inspired by the telegraphic tidings of the landslip, wrote as follows in reference to the choice of safe ground for building:—"This is mainly a geological question, but it is evidently one of the utmost social importance. Among the staff of the Geological Survey of India there is no doubt an officer whose services could be made available to examine and report upon the structure of the ground with reference to this question."

[2] Records of the Geological Survey of India, vol. xiii., p. 277.

Though often tacitly assumed, it is not, I submit, justifiable to conclude that upheavals of mountains left simply plane surfaces for the subærial forces to operate on; ridges and hollows must assuredly have been produced by such disturbances among non-homogeneous rocks.

Naini Tal occupies the bottom of a valley which runs with the strike of a variety of altered rocks, among which much contorted and splintered shales are the most prominent: there are also some limestones, generally occurring in lenticular bands, and indications of the presence of a deep-seated dyke, or dykes, of trap have also been observed.

Where the slopes are gentle the upturned edges of the shales are more or less covered by humus, which in many places supports good-sized oak and other trees. The ledges which are cut into this humus, in order to afford sites for building, serve as collecting-grounds for the drainage, and have been the principal cause of the disturbance of the equilibrium, which has resulted in the landslip about to be described, as well as of many previous ones known to have taken place in the same locality.

The facts connected with the Naini Tal landslip are the following:—On Saturday, the 18th of September, 1880, after about forty hours of continuous rainfall, during which time twenty-five inches of rain fell, at 10 o'clock in the morning a slip occurred on the north-east slope of the valley, which buried a portion of the buildings behind the Victoria Hotel, in which there were at the time some natives and a European child.

By the aid of a party of volunteers and some men from the military depôt, all who had been buried in the ruins, and were still alive were rescued. It was then observed that a stream of water threatened the destruction of the hotel, and the labours of all who were engaged were directed to the diversion of its course. While so engaged, the great slip came down and overwhelmed them, raising the total loss of life to about two hundred persons, of whom forty-three were Europeans.

This last fall is believed to have not occupied more than one-fourth of a minute in its descent, although several large buildings appear to have been carried along on the surface of the *debris* for some distance before they fell. The material of the fall consisted of broken, splintery shales, humus, and vegetation, which rested

upon the upturned edges of a zone of much contorted and shattered shales. After settling down, the surface of the *debris* presented the following appearance:—It was about 600 yards long, of which the lower half dipped at an angle of about 15°, and the upper at from 25° up to the vertical. Owing to the immense quantity of water which had been absorbed into the mass before it began to slide, the whole was in a semi-fluid condition, which was testified, not only by the low angle of repose, but also by the fact that those who ventured upon it sunk up to the knees.

One of the principal objections urged by Mr. Theobald to my view of the origin of the barrier closing Naini Tal was, that those slips "possessed of most mobility, from the greater fluidity of their composition, are in the precise ratio of such fluidity; least capable of . . . bearing upon their surface craggy masses of rock, such as I should term erratics."

This almost *ex cathedra* statement assumes, what is by no means necessary, that the blocks should be carried *on* the surface: and it breaks down altogether when compared with the actual fact, that this Naini Tal slip, by no means an extensive one, as compared with many others known to have occurred in the Himalayas, did carry down blocks 9 or 10 feet in diameter *in* the mass of detritus not on the surface. Heavy rainfall and streams acting on such an accumulation would, undoubtedly, produce an appearance, by the removal of the finer portions, very closely resembling that presented by ordinary moraines, and such an accumulation as that which forms the retaining barrier of Naini Tal.

It would not be difficult to further illustrate these views by reference to several famous landslips which have taken place in Switzerland, in which cases large masses of rock, together with finer materials, have been carried down the slopes of mountains, and spread far and wide in the valleys at their bases. These examples have, however, been fully described elsewhere, so that we may, without more explicit reference to them, pass to the consideration of another variety of soil-cap movements.

Submerged Forests.

To by far the majority of people the appearance of submerged forests or bogs in the vicinity of the coast of any land, whether continental or insular, would be accepted, without hesitation, as being indicative of subsidence. Some observers would probably be tempted, moreover, to calculate the amount of the lowering from the data so afforded. My present object is to discuss the reasons which have led me to adopt the view that such a conclusion may be wholly erroneous. Nay more, in certain cases, the existence of such submerged forests may even afford *prima facie* evidence of upheaval of the land.

I was first led to the consideration of this subject by the existence of apparently very contradictory evidence as to the alteration of levels of sea and land in the case of the Andaman Islands in the Bay of Bengal.

When visiting the Andaman Islands in the year 1868, the evidence appeared to me to favour the view that the islands were slowly *rising*. Although there were no raised coral reefs then known in the islands of this group, there were several creeks between the islands which had become more or less unsuitable for navigation. Thus the channel between the middle and southern islands is said to have been formerly navigable by large boats, though now, I believe, small boats can only go through it. Again, at the head of Port Blair there is a swampy pass containing mangroves through the hilly grounds to the opposite coast, which presents the appearance of having, at no very distant period, been a strait, dividing the South Andaman into two portions. In the more southern, but next adjoining group of islands, the Nicobars, raised coral reefs are of common occurrence, and their absence in the Andamans is certainly remarkable, and not easily to be accounted for if the view that the islands have risen be correct.

The late Mr. S. Kurz contended—from the existence of submerged portions of forests, and even of buildings which were erected during the period of the first settlement of the islands in 1796—that they are now in a sinking condition.

Some of the trunks of trees which he observed had their roots attached to the soil, and were still *in situ;* many of them belonged to species which do not occur in the outer belt of mangroves, but

in the next succeeding zone inside it, or in a zone at the foot of cliffs, in which positions there is no outer belt of mangrove swamps owing to the steepness of the shore.

On the one hand, the fact that the above-mentioned straits have become unnavigable may be due to either ordinary or extraordinary silting up. By extraordinary, I mean wholesale landslips, such as those in Patagonia, and therefore their condition might be coincident with a general subsidence. On the other hand, mere encroachments of the sea may produce appearances which would be mistaken for actual subsidence. This last may be the explanation in the case of the above-mentioned buildings, for instance.

Now, without attempting to discuss the conflicting evidence in this particular case, as further examination of the islands, especially with reference to the views put forward below, should, I think, first be made, I pass to the consideration of the general question as to the manner in which such apparently conflicting evidence may be reconciled.

The subject has already been dealt with in a Paper by Dr. Coppinger, which was read before the Geological Society of London last year.[1] The phenomena which he describes were observed in Western Patagonia, where the soil-cap slides downwards over sloping surfaces of rock, carrying with it not only the trees, ferns, and mosses on its surface, but also a *moraine profonde* of rocks, stones, and trunks of trees, with which the valleys and lakes become filled up.

Anticipating that subsidence might be suggested to account for some of the phenomena, he points out that the existence of raised beaches, and the traces in the rocks of stone-boring mollusca above present sea level, prove, on the contrary, that elevation has taken place. Removal by water of the lighter portions of the material thus brought down leaves a remnant of blocks, which are often perched on one another in a similar manner to those which have been transported by glaciers; and in the particular region in question there are such glacial moraines conveniently situated for comparison.

These appearances were contrasted with those of the celebrated stone rivers of the Falkland Isles, which Sir Wyville Thompson[1]

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[1] Quarterly Journal of the Geological Society, vol. xxxvii., 1881, p. 245.

has attributed to the movements of the soil-cap, which has in part derived its motion from the expansion and contraction of the spongy mass, due to varying conditions of moisture and comparative dryness.

Several speakers, when discussing Dr. Coppinger's Paper, afforded testimony as to the probability of such a cause being capable of explaining many accumulations of blocks and breccias in both recent and early times, while Sir John Hawkshaw showed that movements of the soil-cap, and with it of rocks, were only too familiar to engineers, and that, in some cases, they continued for many years after once the surface had been disturbed.

In this instance of Patagonia, then, we have a beautiful example of the contemporaneity of two apparently contradictory phenomena—(1) a rising of the general mass of the land; and (2) a subsidence of the soil-cap. Generalizing from this, it would perhaps be not too much to say that, given certain relationships between tracts of land and their soil-caps, an upheaval, owing to the disturbance of equilibrium, would invariably be followed by a subsidence of the soil-cap. Detrital matter which had settled down at its angle of repose must, on the elevation of its sustaining surface, find a new position at a lower level, and thus I believe may, in some cases, be explained the presence of submerged forests and bogs on the one hand, and accumulations of glacial-like *debris* on the other.

In regions where there is a heavy rainfall, and also in those where the protecting effects of vegetation have been removed by the cutting down of forest, subsidences of the soil-cap, as is well known, are of common occurrence without any necessary exhibition of regular landslips. There are tracts in the Himalayas where, at the cost of the primeval forests, tea-gardens have been established on the slopes, and where, after a few years, the tea-bushes have been left starving on the almost bare rocks owing to the subsidence of the soil into the valleys.

It is far from my intention to make any sweeping, or general application of these agencies, to account for accumulations of rocks in different geological periods for which a glacial origin is generally claimed. My object is to draw the attention of geologists to

[1] Voyage of the Challenger—*The Atlantic*, vol. ii., p. 245.

them, as their potency is, perhaps, not so fully recognized as it should be.

I do not profess to be an anti-glacialist; but where so much depends upon the fact of glacial epochs having existed during different geological periods, it seems to be due to the physicists that geologists should use the very utmost caution in the matter.

Here I would refer to a case where there appears to me to be fairly presumptive evidence of the existence of a glacial epoch at so early a geological period as the Cambrian. Recently, at Gairloch, in Rosshire, I examined the varied traces of the operations of the glacial period in that neighbourhood, and while doing so I was impressed with the belief that certain Cambrian breccias lying in valleys, scooped out of the surface of the Laurentian rocks, afforded evidence from their position, much more than from their lithological constitution, of the existence of a glacial period in those early times. Modern glacial action appears to have re-scooped the valleys which must have already been in existence when the breccias were deposited, and therefore it may be argued that they were originally carved out by the same tools. This is of course not quite conclusive, as it would be if, in support of it, glaciated surfaces were found underlying the Cambrians; but as yet I am not aware that any such have been discovered at Gairloch

XXII.—ON RECENT ADDITIONS TO OUR KNOWLEDGE OF THE GOLD-BEARING ROCKS OF SOUTHERN INDIA.

By V. BALL, M.A., F.R.S., F.G.S., Professor of Geology and Mineralogy in the University of Dublin.

[Read, February 19, 1883.]

Three years ago, when I read before this Society an account of the "Mode of Occurrence and Distribution of Gold in India," I pointed out that the available information as to the geology of some of the regions which were then attracting the notice of gold mining companies was very imperfect.

Recently this deficiency has to a considerable extent been removed by the publication of a Paper by Mr. R. B. Foote, of the Geological Survey of India,[1] in which he has suggested the existence of a correlation between the gold-bearing rocks now known to exist at the several localities where mining operations have commenced, and at some others where the occurrence of auriferous sands has been ascertained.

The subject, as I propose to treat it, deals especially with the geological aspect; but since so large an amount of capital—upwards of £3,000,000—has been invested in companies, it is natural that a great number of people should regard with particular interest the economic side of the question; for this reason, therefore, I think it desirable that I should make some preliminary remarks on the productiveness of Indian mines.

In the absence of detailed and thoroughly trustworthy accounts of operations at particular mines, it is necessary to be somewhat general in our statements, and yet this is a subject by no means well suited for such a method of treatment.

About a year ago I was challenged publicly at a meeting in London to state at what depth the quartz reefs would be most

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[1] Notes on a Traverse across some Gold-fields of Mysore, Records of the Geological Survey of India, vol. xv., 1882, p. 191.

auriferous, and privately I have been interrogated to the same effect. The supposition that at a given depth gold would be found in comparatively great abundance is one that has received some currency from the fact that certain reefs in Australia have been worked with most profit at great depths. It is a supposition which has proved very convenient for those companies which are as yet unable to show any returns to shareholders for the large sums of money which have been expended.

Now, if we attempt to apply such an hypothesis to the region in question, we find ourselves at once landed in a maze of absurdities. The only meaning that "depth" can have in this connexion is the vertical distance downwards from the surface, which latter is, in this particular case, a most variable datum, varying in level not only by hundreds, but even by thousands of feet, since some of the reefs are believed to be traceable from high elevations on the Wynand plateau, 3000 feet above the sea, downwards to the low-lying tracts at its foot.[1] These differences in contour being mainly due to subaerial denudation, it stands to reason that a depth of, say 200 fathoms, on a reef referred to the sea-level standard, is a very different thing when applied to a mine on the top of a lofty plateau to what it is when a mine at its foot is in question.

Each mine, therefore, can only be discussed on its own merits, and the outcome of all that has been done in the exploitation of gold-bearing reefs may be expressed by a truism which carries with it no hypothesis. It is simply this—that the richest part of a reef is that which, when experimentally tried, contains most gold. Similarly situated and neighbouring reefs may be found to exhibit similar phenomena; but to expect reefs situated at great distances from one another, and at varied altitudes above sea level, to exhibit any close resemblance in their characters, when mined to the deep, is a manifest absurdity.

Of the wide-spread distribution of auriferous rocks in certain parts of India there can be no doubt; and it is strange that we should not yet, after three years, be in possession of more positive evidence of their productiveness. Eighteen months ago I heard of cases of managers of mines being pressed by their London directors to push their works onwards to the deep, the natural conclusion being

[1] King, Records of the Geological Survey of India, vol. viii., 1875, p. 36.

that the reefs near the surface had not proved rich enough to work; so that hopes for the future depended on a hypothesis as to their improvement to the deep, which had no real justification in fact. Indeed, I might add to this that in some instances these operations were, I believe, carried on where there was no true reef exposed at the surface.

I have carefully watched for consistent evidence of any of the mines proving productive to a profitable extent. There is no *à priori* reason against the capability of some of them becoming so; but rather the contrary. Still shareholders of the companies, with scarce an exception, are now complaining that there are no results to justify the confidence which they have shown in the hopes held out to them of returns at dates now long past.

I take this opportunity of referring to a large volume which has recently been published. The author, when noticing my writings on this subject, though commending my caution, describes me as being a pessimist, and thereupon complacently incorporates into his book, without the use of inverted commas, nearly forty large pages of facts which I had most laboriously collected for my chapter on Gold in the Economic Geology of India.

The term pessimist when thus used must be intended to indicate a person who bases his opinion on well ascertained facts—and on them alone—and who rejects, as unsuited to his purpose, the high-flown and always sanguine views of writers whose language sometimes keeps pace with their interests. Such, at least, was my professed method; and it may even prove that the opinion I expressed, guarded as it was, was only too favourable. I certainly believed that long ere this there would have been, in the cases of some of the companies, more tangible results than I have yet been able to hear of.

Mr. Foote has ascertained that, traversing the granitic gneissose rocks, which form the uplands of Mysore, there are several parallel zones of schistose rocks in which all the principal known gold-bearing localities are situated. Two of these zones are traceable for several hundreds of miles, and their width is in one locality, at least, eighteen miles. Although the nature of the relations

eixsting between these zones and the neighbouring rocks do not appear to have been as yet very fully elucidated; still, in general terms, they may be described as being formed of schists which rest in synclinal troughs upon the older granitic gneissose rocks. The schists are of various kinds—hornblendic, chloritic, hæmatitic and micaceous, the latter passing into quartzites, and in one of the zones there is a very remarkable and interesting bed consisting of an enormously thick conglomerate of pebbles and boulders of compact gneiss in a greenish-grey foliated chloritic matrix. Traversing these schists, &c., occur quartz reefs, in which traces of gold are found, and with the presence of which the existence of the auriferous deposits generally appear to be connected.

At one locality, near Honnali in Mysore, there are a great number of reefs traversing chloritic rocks. To them is traceable the source of the gold which is found distributed through the red soil, covering the neighbouring low country. Mr. Foote describes having witnessed the prospecting of some of these reefs by an experienced Californian miner, the results having been satisfactory. The quartz was found to contain gold, which was visible in grains and scales, scattered pretty freely through the mass. The "Turnbull" reef, which was the most promising of the group, could be traced, with some breaks, for a distance of nearly six miles. "The results of many washings, both of crushed quartz and of the red soil taken from many localities and various levels," were in the majority of instances "satisfactory." Significantly it is remarked, that the prospects in this case are certainly greater than those of other companies whose shares are, or were till lately, favourably quoted.

Regarding the Kolar field, Mr. Foote considers that the reefs found there, though small and inconspicuous at the surface, are true fissure veins or lodes. The quartz composing them is, he writes, "a bluish or greyish-black diaphanous or semi-diaphanous rock which is remarkably free from sulphides (pyrites, galena, &c.) of any kind. The gold found is very pure and of good colour. Several washings of crushed vein stuff were made in my presence at the Urigam and Kolar mines with really satisfactory results, the quantity of gold being very appreciable." The samples, it is said, were

not picked ones, by which it is to be presumed that we are to understand that they were not exclusively from the casing walls of the reef or from the feeders.

One report which I received from this locality was, however, that the thin casing walls of the reefs and the feeders or leaders from them, alone contained gold in paying quantities, the bulk of the reefs not containing gold sufficient to pay the cost of extraction. Similar observations have been made by Mr. King with reference to some of the Wynand reefs. Where such is the case the matter narrows itself into a purely mining question, whether in following to the deep and extracting these casing walls the expense of dealing with a comparatively large proportion of practically barren rock will not exceed the produce from the paying portion. The feeders, in the majority of cases, are probably of too limited and capricious a distribution to admit of being mined to any extent.

It is, to the best of my belief, fully two years since some of the engines and stamps were set up at Kolar, so that shareholders cannot be accused of undue impatience if they now ask for results.

Regarding the geological age of these gold-bearing rocks, it seems probable that they belong to the lower transition or submetamorphic series of India, the representatives of which, as I showed in my previous Paper, are also auriferous in Bengal.

In lithological characters, especially in the prevalence of chloritic schists, there is a very close resemblance. Invariably I found in Bengal that chloritic schists, traversed by quartz reefs, were to be found in the vicinity of those tracts where the auriferous sands were richest. The coincidence was far too constant to have been accidental.

I cannot but believe that there are localities in India where gold, in paying quantities, exists. A failure upon the part of a number of the companies to produce profitable results would not necessarily invalidate this opinion. Some have acquired properties which are, probably, worthless, while others have a heavy burden of capital which may prove most detrimental to their prosperity; but the most competent men who have examined the properties are unanimous in asserting that some of the mines are of promise.

A large measure of success would be of enormous importance to India, as the production of gold there would tend to reduce the rate of exchange which at present causes so much loss to the public and to private purses. At the same time, to be appreciably felt the outturn should amount to several millions sterling, otherwise it would not influence the enormous transactions between India and Europe: these at present are the cause of a process of depletion which is most detrimental to the best interests of the former country, while it does no good whatever to the latter.

XXIII.—ON THE POSSIBILITY OF GOLD BEING FOUND IN QUANTITY IN THE CO. WICKLOW. BY GEORGE HENRY KINAHAN, M.R.I.A., &c.

[Read, February 19, 1883.]

IN a Paper read some little time since before the Society, "On the Mode of Occurrence and Winning of Gold in Ireland,"[1] the writer gives a very exhaustive account of the Wicklow Placer mines. Since then our Honorary Secretary, in his admirable report on the Economic Geology of India,[2] seems to suggest "that very little more gold is to be found in the Gold-mine Valley"; and the object of this Paper is to lay before the Society the general facts of the case.

From the explorations in different portions of the world, it has been learned that in connexion with a Placer mine, gold may be found—first, in the mother-rock (*reefs or veins*); second, in the higher shallow alluvium of the valley (*shallow placers*); third, in the lower deep alluvium of the valley (*deep placers*); fourth, in the alluvium of the beds of the high, now dry, supplementary streams of the ancient or primary valley (*dry gulch placers*); and fifth, in the shelves, or high level flats, on the sides of valleys (*shelf, reef or bar placers*),[3] the latter being the relics or records left of the floor of the ancient primary valley—they proving that prior to the present time the gold was in the first instance deposited in a comparatively wide shallow valley; while the alluvium of the present stream is the rewashed drift of the ancient valley mixed with newer detritus. Now in modern times, in none of the valleys of the Co.

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[1] Gerrard A. Kinahan, Journ. R.G.S.I., present vol., p. 135.

[2] Geology of India, Part iii., "Economic Geology," by V. Ball, M.A., F.G.S.

[3] The term reef is, in part, confusing, as "reef mining," as used in some countries, refers to the crushing up of the quartz veins or reefs—while in other places the same term "reef" is applied to the high level flats.

Wicklow has gold been found, or even looked for, except in the first, second, and fourth cases.

The gold of this portion of Wicklow has been found sparingly, *without tin ore*, in " black sand," and more abundantly in connexion with tin ore and wolfram. The Gold-mine valley opens into the valley of the Aughrim River at Wooden Bridge, four miles inland from Arklow; in the south branch of the Gold-mine river gold and tin were found N. and N.E. of a point half a-mile S.S.W. of Clonwilliam slate quarry; gold and a quantity of tin were found also in the south-west branch of the Gold-mine river, N.E. of the ford (*A*) of Ballinasilloge; and in the Coolbawn valley, immediately on the west of the Gold-mine valley, gold and tin were found, in quantity, at a point (*B*) one mile N.N.E. from the summit of Croaghan Kinshella. It may, therefore, be naturally suggested that if a "mother-rock" exists, it ought to be found somewhere near one of these points; while, as far as can be learned from the records, no researches have been made in connexion with such an idea. Mills indeed suggested that the high ground of Ballinasilloge, to the north of *A*, should be tried, but his suggestion was overruled by Weaver and Kirwan: there is also the high land of Knockmiller, between *A* and *B*, that has not been tried; while immediately eastward there is more untried high land, although in the valley of the townland of Mongan there are indications that strongly suggest the presence somewhere thereabouts of a mineral vein. It therefore appears to me that until after the high land in these localities has been investigated it would be rash to assert no gold reef exists.

To the westward, in the upper portion of the Tomnaskela river valley, gold has been proved to exist, but never worked for. In the Coolbawn stream and its eastern tributaries all the diggings were shallow, the search being abandoned when the head of drift became twelve or fifteen feet deep. However, three miles to the N.W., near the Darragh water, where the alluvium was again shallow, the gold was worked. There is, therefore, in the Coolbawn valley three miles in length of untried deep alluvium.[1]

In the valleys of the S. W. and S. branches of the Gold-mine

[1] Weaver began trials in this deep ground; but when he found the drift was deep enough to prevent the country people from working there, he abandoned them, deep works being contrary to his instruction.

river there are no workings more than thirty feet deep, while nearly all of them are less than twelve or fifteen feet; there is therefore, in this valley at the least, over a mile of untried deep ground.

In connexion with the Darragh water or Aughrim river, the gold-bearing tributaries are:—the Tomnaskela river, the Coolbawn stream, the Ow river, the Kilmacreddin stream, the Clone stream, the Ballintemple stream, and the Gold-mine river; yet the alluvium of the valley has not yet been tried, except at Ballycoog steps, where gold was proved. The distance from the inver or mouth of the Tomnaskela river to the Lower Meeting at Wood bridge is over eight miles.

Gold has been found in the sand of the Ow and in the alluvium of its tributary, the Mucklagh brook; the untried valley from the Mucklagh brook to the Darragh water valley being over six miles in length.

Only the shallow alluvium of the upper tributaries of the Macreddin stream have been worked, there being a length of over three miles of deep alluvium between them and the Darragh water.

In connexion with the Ovoca, there is gold in the gossan of the Ballymurtagh, Upper Cronebane, and Connary mines, in the river gravel at Castle Macadam, and in the alluvium of the Darragh water and its tributaries. There is, therefore, from the Ovoca mines to the sea at Arklow a length of over six miles of untried deep alluvium. So much for the untried deep and shallow placers in the neighbourhood of the Gold-mine Valley.

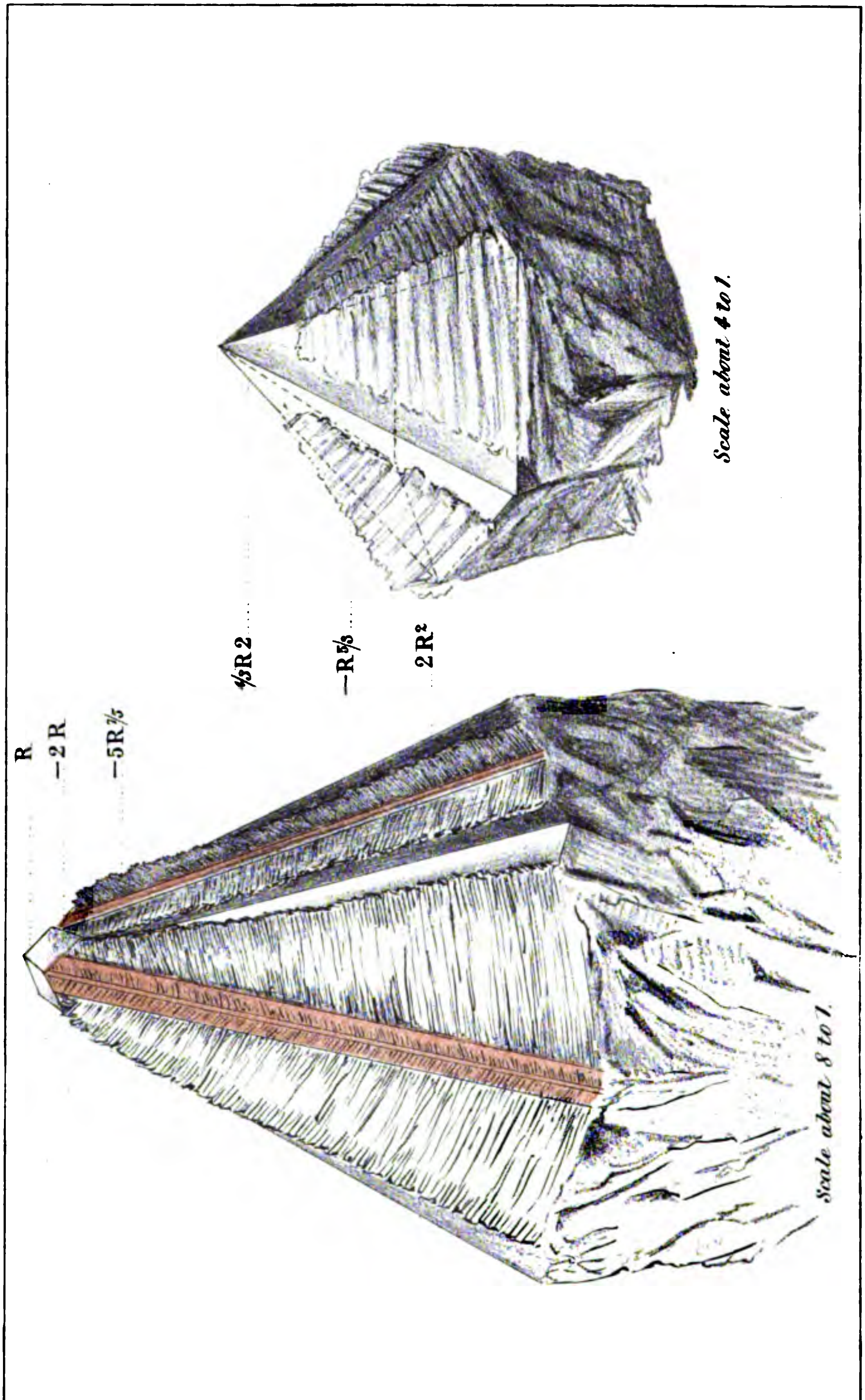
In connexion with the S. branch of the Gold-mine Valley, one or two "dry gulches" were worked by Weaver, who got in them "large gold." Nowhere else does there appear to have been exploration made in search for "dry gulches."

The relics of the more ancient valleys, that is, "shelf," or "bar placers," have never been looked after; yet in many places there is a possibility, if not a probability, that such golden relics might be found. Experience in America and Australia has proved that such deposits usually, although not always, occur in the shelves at the convex side of valleys, below the level of the source of the gold; and such shelves, possibly gold-producing, are very conspicuous in places along the valleys of the Ovoca, the Darragh water, and the Gold-mine river, at heights below the known points at which

the gold was found in quantity associated with tin ore and wolfram. None of them have ever as yet been explored.

There are other places in this neighbourhood, such as Ballinglen and the Tinahely streams, in which gold has not yet been recorded or tried for, although the indications would suggest its existence; but these it is unnecessary further to refer to.

In conclusion, however, I would submit to the Society, that to me it appears rash to give an opinion on the non-existence of gold, while the miles of alluvial ground now enumerated still remain unexplored, or while no attempt has been made to explore the shelves of the valleys.



Glenariff Calcite Crystals.

J P O'Reilly, del

Forster & Co Lith, Dublin

XXIV.—ON THE CALCITE CRYSTALS FROM THE IRON MEASURES OF THE COUNTY ANTRIM. By PROFESSOR J. P. O'REILLY, C.E. (Plate VIII.)

[Read, February 19, 1883.]

In the very interesting Paper read before the Royal Geological Society of Ireland, April 11th, 1881, by Mr. Philip Argall, on the "Tertiary Iron Ore Measures of Glenariff Valley, Co. Antrim,"[1] he makes frequent mention of the "aragonite crystals" which accompany the ores and are found in geodes or vugs of the roof of the ore bed, or in cells of the amygdaloidal dolerite along with zeolites, as also at other points of the deposit in fine acicular crystals. He remarks, p. 158: "Hence a display of crystals (aragonite) on the roof is regarded by some as a sign of poverty; similarly as a display of spar crystals in a standing vein indicates poverty of mineral matter in the percolating fluids when the run was being filled." At page 161 he says, "when approaching a dyke, cracks in the pavement are frequently filled with acicular crystals of aragonite."

Mr. Argall very kindly procured for me the linings of a couple of fine geodes, and in the accompaning letter explained by a sketch the position of the vugs or cavities relative to the ore bed in which the crystals are found. Subsequently, in October last, Professor Hull handed me for the Museum collection of the Royal College of Science some specimens of acicular crystals from the same contact found at Cushendal, Co. Antrim. I had previously been engaged in examining the crystals of the vugs forwarded me by Mr. Argall, and from the densities obtained had reason to consider these crystals as being really calcspars. A further examination of the acicular crystals presented by Professor Hull lead me to the same conclusion in their regard, and I now beg leave to submit the results of this examination from the points of view of density, crystalline forms, cleavage, and hardness.

[1] Journ. R.G.S.I., present vol., p. 98.

The density of the acicular crystals presented by Professor Hull was found 2·71.

That of part of a honey-coloured crystal presented by the same 2·71.

The density of calcspar crystals is given at 2·6 to 2·8.

And for the purest crystals 2·72.

Whereas that of similarly pure aragonite crystals varies from 2·9 to 3·00.

It may, therefore, be concluded that from this character alone the crystals in question are calcspars. The further examination of the crystalline forms, cleavage, and hardness, still further confirms this conclusion. The crystals are scratched by aragonite, and the cleavage is very distinctly rhombohedral, and in no way that of aragonite. The crystalline forms are sufficiently distinct in the small acicular crystals to allow of measurement, and are clearly referable to the rhombohedral forms of calcspar. Thus the acicular crystals show on the sides the zigzag striations characteristic of certain scalenohedral forms and the angles measured on the long, short, and middle edges, give sufficiently approximatively the values corresponding to the scalenohedral form $R12$.

Long edge,	calculated	angle,	125° 47′,	found	125° 30′.
Short edge,	„	„	114° 50′,	„	114° 51′.
Middle edge,	„	„	167° 35′,	„	—

These crystals are terminated by the forms

$4R$, terminal edge, ... 65° 50′,

$-2R$, „ calculated angle, 78° 51′, found 78° 00′,

and R.

The honey-coloured partial crystal from Cushendall presented by Professor Hull shows the forms

$R12 - 2R$, and cleavage terminal forces of R.

The crystals occurring in the geodes of the iron ore bed present scalenohedral forms oscillating in a remarkable manner, and in the central zone of each face a band, or red stripe strongly marked, and representing the rhombohedral form $-2R$. The examination of several of the crystals shows that on either side of this band, itself somewhat rough, there is an oscillation of scalenohedral

forms, marked by ridges and furrows running nearly parallel to the basal section, and giving rise to a rounded face. These oscillating forms represent the scalenohedrons $-2R^2$ and $-5R\frac{7}{5}$.

$-2R^2$	Long edge,	calculated,	153° 16′,	found,	153° 57′
	Short edge,	„	92° 9′,	„	93° 10′
	Middle edge,	„	135° 19′,	„	135° 25′
$-5R\frac{7}{5}$	Long edge,	„	164° 59′,	found,	165° 24′
	Short edge,	„	76° 54′,	„	75° 58′
	Middle edge,	„	132° 01′,	„	134° 30′

The roughness of the faces, and the rounded faces of the middle edges rendered closer approximation difficult. The oscillation of these forms gives to the surface of the crystal a feathered appearance, the feathering proceeding out symmetrically on either side from the red stripe representing the face $-2R$.

In other vugs occurs a combination of forms somewhat different. Thus, there is found a central pyramid of which the faces present the roughness of a ground glass plate with cleavage planes traversing them at regular intervals. This form represents the pyramid $\frac{4}{3}R2$:

Calculated polar edge, 135° 51½′, found, 135° 57′.

On the alternate polar edges appear in process of formation, and in different stages of that process, the faces of the scalenohedron $-R\frac{5}{3}$:

Long edge,	calculated,	161° 53′,	found,	161°.
Short edge,	„	101° 55′,	„	101°.

This last form is rarely complete, and its faces rarely cover the whole of the underlying pyramid, and in the same manner as in the case of the previously described crystals, leave a space or band along the middles of the alternate pyramidical faces, but without any red stripe.

The conditions having led to the deposition of the red mineral matter (peroxyde of iron apparently), present interest in so far as they might lead to an estimate of the temperature of the solution from which the crystals were formed. The only record existing as to actual experiment in this respect is that of Sénarmont (An. de Ph. and Ch., t. xxx. p. 129), who transformed the hydrated peroxyde of iron into anhydrous peroxyde by heating it in a

closed vessel at 180° C. in presence of water, or in a saturated solution of chloride of magnesium or chloride of calcium. The product obtained was red, amorphous, and resembling the common variety of natural sesquioxyde of iron. Why the central band of the crystal should alone present this oxyde is not so easily explained, unless by the hypothesis that crystals of either carbonate of iron or iron pyrites were deposited on this surface, and then subsequently transformed into peroxyde. That certain faces of crystals induce, or facilitate such deposits is well known; and that the state of the surface of the face is an essential factor in the phenomenon is also well known: the primary cause is, however, less clearly explainable.

That no precise conclusions could be drawn from the presence either of aragonite or calcspar as regards the temperature of the solution from which the crystals were deposited would appear from the synthetical experiments of G. Rose, which tend to prove that both calcite and aragonite may be formed in warm solutions. The conclusions of a review of all the synthetical experiments made up to the present relative to these two minerals are thus stated by Messieurs Fouqué and Levy in their remarkable work, "Synthèse des mineraux et des roches" (1882), p. 203:—"In the greater number of cases, natural calcite and aragonite appear to result from the decomposition of solutions of bicarbonate of lime more or less concentrated, and more or less warm. The crystals formed affect the rhombohedral, or rhombic forms according to the temperature at which the crystallization takes place."

In this case the presence of the red band of sesquioxyde of iron would tend to prove that the solution, at one particular stage, was warm, and as this was a final stage, the probability is that the calcite crystals were formed from warm solutions of bicarbonate of lime.

XXV.—A GEOLOGIST'S CONTRIBUTION TO THE HISTORY OF ANCIENT INDIA, BEING THE PRESIDENTIAL ADDRESS TO THE ROYAL GEOLOGICAL SOCIETY OF IRELAND. By PROFESSOR V. BALL, M.A., F.R.S., F.G.S.

[Read, March 19, 1883.]

It has devolved upon me, somewhat out of the ordinary course, to deliver to you an address at the commencement of my term of office. The ill health of the late Professor Leith Adams precluded his addressing you last year, and the duty was undertaken by the Rev. Dr. Haughton, whose long connexion with this Society rendered it particularly fitting that he, who for many years has been its principal stay and supporter, should be our President on the occasion of the celebration of our fiftieth anniversary.

Having completed one year of office he has resigned, and proposed my election as his successor. This proposition having been adopted by the Council, and ratified by the Society at large, I find myself placed in this honourable position at a period when my service to the Society has been but of short duration, and my connexion with the progress of geological research in Ireland of still less mature age.

I have to thank you very sincerely for the high honour you have conferred upon me. It is a source of extreme gratification to me to find myself enrolled on the now long list of Presidents of the Royal Geological Society of Ireland. Since that first meeting of the Society, held in the Provost's house in November, 1831, there have been periods of great prosperity, as necessarily there must have been, since so many men of distinction who have held office were active in the furthering of the objects expressly laid down at the time of incorporation.[1]

[1] At a meeting held at the Provost's house November 29, 1831, it was resolved:—"That the gentlemen present do form a society for the purpose of investigating the mineral structure of the earth, and more particularly of Ireland, to be called the Geological Society of Dublin, and that to promote this investigation the Society shall hold periodical meetings, collect books, maps, specimens, and other objects relating to geology and mineralogy, arrange the collection in a museum according to the most approved classifications, publish papers and essays, and contribute in every other possible manner to the progress of geological science."—*Extract from Minute Book.*

Our Minutes, which have been carefully kept for the half century, and the attendance-books, which are still extant, contain a most interesting record of the past. We can learn from them that the subjects discussed at the evening meetings served to attract and bring together, at one time or another, all those who have felt an interest in the progress of geological research in Ireland. There were many, too, who were perhaps more directly identified with other branches of science; still, by their presence at the meetings, they conferred upon the Society a status and influence which were widely felt at the time.

Looking down that roll of past Presidents, there may be seen the names of many men whose accomplished work has secured for them a world-wide reputation, and among them, perhaps, I may be permitted as a personal matter to refer to those to whose teaching and encouragement I owe it, that twenty years ago I adopted the career of a professional geologist. Drs. Haughton and Apjohn and Professor Jukes were my instructors here, and by Dr. Oldham I was inducted into the duties of an Indian field geologist. It is natural, therefore, that I should feel honoured at being appointed as their successor, and it will be readily understood that I experience a very special gratification at being appointed to succeed the structor of my earliest youth—my father, who exactly thirty years ago, or in 1853, delivered the Presidential address.

It would be wrong were I to conceal the fact that we are not now in a prosperous condition. The Society has seen better days, but let us hope not its best. Just at present, from whatever cause, possibly from superior attractions afforded by other branches of science, active interest in geology appears to exist only among a limited number.

We stand in need of more members who will not only, by their subscriptions, place the Society in an improved position as regards its means for meeting its requirements, but who will, by contributing Papers, enable us to produce a journal which, from its variety and originality, will continue to prove acceptable and useful here in Ireland, and will serve to increase the Society's reputation in distant lands.

The machinery exists, and is now in active operation, for exchanging our publications with those of the principal learned societies all over the world, and we have the testimony of our

correspondents that our journal is acceptable in exchange for the publications of other societies, of which many possess a high intrinsic value.

But those who have to provide the material for the journal are not unmindful that it falls short, not only of being what it ought to be, but even of what it might easily be, if all geologists in Ireland would give their aid.

We want a larger income to enable us to provide fitting illustrations. Many Geological Papers require, in order to be intelligible, more or less costly illustrations, and writers of such Papers would, doubtless, be more willing than they are at present to use our journal as their medium of publication, were they assured that such illustrations could be given with their Papers. To a certain extent our present association with the Royal Dublin Society enables us to produce the journal at a less cost than would be the case were we working single-handed; but in our straitened circumstances we have hitherto been enabled to avail ourselves of this aid as regards illustrations to but a very limited extent.

Those of our members who contribute with most regularity to the journal—and the list of them is not a long one—give the Society not only their best and most important Papers, for which they might obtain a wider publication elsewhere, but they also give Papers of minor importance, the professed object of which is to provide the Society with material for its meetings.

This is, perhaps, a not altogether healthy state of things; a longer list of contributors, and fewer contributions from the same individuals, would indicate a wider basis of support. In purely provincial societies, whose existence is due to the exertions of a few energetic individuals, such is to be expected; but it behoves us all to do our utmost to place and keep this Metropolitan Society in a higher rank than is ordinarily attained by a merely provincial society. The Royal Geological Society of Ireland is entitled by its past history and reputation to the support of everyone interested in the geology of Ireland in particular, and of residents in Ireland who are interested in general geology, all of whom we call upon to contribute their aid in the directions above pointed out.

No one has realized the Society's state of affairs more fully than our outgoing President; he naturally feels anxiety for its future, while its existing condition ever presents itself to him in

his capacity as Treasurer. As a means of quickening the public interest in our operations, and of aiding in the development of Ireland's industrial resources, he has proposed a scheme to the Council, the outlines of which it is now my duty to announce to you.

Dr. Haughton considers that the past history of the attempts which have been made to develop the mineral resources of Ireland affords a safe guide as to the particular directions in which that development may be most profitably prosecuted. He accepts it as demonstrated by experience, which has been purchased at great cost, that the metallic ores occurring in this country—absence of suitable fuel, &c., being taken into consideration—are, with one notable exception, not of great present value. He further considers it to be the case that the prospect of profitable exploitation on an extended scale afforded by the coal-fields of Ireland is not very encouraging.

There are, however, on the other hand, mineral resources as to the abundance and value of which there is no doubt whatever, and to these he proposes that certain members of the Society should direct their particular attention, with the view of drawing up a series of reports or monographs which will, it is hoped, prove of practical commercial value.

The scheme has so far advanced that the duty of preparing these reports has been allotted and undertaken as follows:—

I. Paving Setts: Dr. Haughton.
II. Antrim Iron Ores: Professor Hull.
III. Slates: Professor O'Reilly.
IV. Ornamental Building Stones: Professor V. Ball.
V. Cements: } Not yet allotted.
VI. Pottery Clays: }

The co-operation of all whose positions and opportunities may enable them to give aid in the way of statistics or suggestions in reference to these subjects is earnestly solicited, and all aid so afforded will be duly and thankfully acknowledged.

We hope to show by these reports that, while on occasions we may occupy ourselves with questions of a more or less abstract nature, we are not unmindful of what we conceive to be our duty

in respect to the application of scientific treatment to practical subjects.

In support of the statement made above as to the commercial value of some of the productions which have been enumerated, reference need only be made to the large export trade which is done in Antrim iron ores; to the granite setts and ornamental granites which are exported from Newry, the former having been sent as far as Chicago, and the latter to Bucharest, and it may be added as being, perhaps, still more noteworthy, to Glasgow. The roofing slates of Ireland are not as yet by any means so largely employed as they deserve. I say this while fully conscious that they sometimes have defects which militate against their universal employment.

Every resident in this city is aware that there are here in Dublin a number of chemical works engaged in the preparation of manures, bleaching powders, acids, &c. Although I know it is not the case in all, still at one of these works I found recently that no one of the substances of mineral origin which were used in these manufactures was the product of Irish soil.

As might be expected, all the metal-work of the machinery and the lead of the acid vats had been imported. The phosphates were from South Carolina and Cambridgeshire. The pyrites from Spain, after burning it, is reshipped to Swansea, where it is treated in the wet way to extract a small percentage of copper present in the ore. The manganese and the salt were also imported, and so were the large stone slabs used in the construction of the acid vats. Nay, more, the very limestone used in the manufacture of bleaching-powder comes from England, although Ireland is so especially a limestone country; and, in the Co. Antrim, possesses chalk of exceptional purity, which is, to some extent, exported from Belfast to England, to return, perchance, as bleaching-powder, for the use of the linen works.

Nearer at hand to us, at Skerries, I am informed, that a limestone of good quality is obtained; yet neither it nor the Templemore limestone, also well suited to the purpose, are used at the particular works I refer to, though they are at others.

The, as yet, unallotted subjects upon which we hope hereafter to publish reports, namely, the cements and the pottery clays, are certainly not of least importance. The materials are known to

exist, and probably will be found in some quarters where they have not as yet been discovered. There seems to be every prospect of cements being more extensively used in the future than they have been in the past, and it is for the benefit of our buildings, no less than for that of the industry itself, that a cheap local supply should become abundant.

As for pottery clays, Belleek affords ample testimony of the presence of suitable materials, and the capabilities of native talent. Why that particular industry has not yet proved commercially successful I cannot say—it has certainly deserved to be so.

I shall not further encroach now upon these subjects, which belong to the forthcoming reports, and will, no doubt, be discussed in them. Nor shall I enter upon any discussion as to the political questions which influence, in a superlative degree, the development of this country's industrial resources.

No fact is more generally acknowledged than that capital is sensitive. Each possessor of it illustrates this truth by the manner in which he makes his investments. He may make mistakes, and he may send his capital to countries of which he knows nothing whatever, but he does not ordinarily invest his property in a country while he knows it to be in a condition of unrest.

Circumstances, it is to be hoped, will bring about a condition of rest and renewed confidence here, and, in the meantime, we purpose preparing information on the above subjects, which will serve to indicate directions in which capital, when available, may be invested with the best prospect of future profit.

A question has informally arisen among some of the Members in reference to the circumstances under which we at present hold our meetings, whether we should not be in a better position as regards the accession of new and active interest of old Members, if we had a more distinct local habitation, with our own library and so forth. But this question was, to the best of my belief, fully decided some years ago by circumstances which, while the Society regretted, it could not control. There are, probably, few younger Members of the Society than myself here present, and so I will not say more on a subject of which most of you know more than I do. But this may be said as regards the present, we don't know how far our orbit of revolution as an independent body is from its completion. Fifty-one and a-half years ago we started on our career

as a satellite of the Royal Irish Academy; we are now in close proximity with another body, but whether we shall merge into it, or on the conclusion of our period be re-absorbed by our original parent, time only can determine. Having entered, however, on the second half-century of our existence as an independent body, let us hesitate before we take any step which may hasten our reaching a condition of *nirvana*, as our doing so would have one effect, among others—it would deprive posterity of the supreme gratification of celebrating our centenary.

As on an occasion like the present some latitude is permissible in the selection of a topic, I have chosen the following as the special subject of my address:—

A Geologist's Contribution to the History of Ancient India,

Being an attempt to identify the sources whence the mineral productions were derived, which are mentioned by the Historians of India from the earliest times to the close of the eighteenth century.

The subject of this Paper first attracted my attention in connexion with the preparation of the accounts of the diamonds and gold of India, read before this Society in the year 1880. Subsequently, when collecting materials for my volume on the Economic Geology, I found that there were many obscure historical notices upon which our modern knowledge of the geology of that country was capable of throwing much light. Although some of the translators and critics of the ancient writings, which afford the principal part of my data, have sought to illustrate their authors' meanings by references to the results acquired by the systematic examination of the mineral resources of India in recent times, still there is often a considerable amount of vagueness and inaccuracy in these references, and, so far as I can ascertain, there has not as yet been published a comparative and categorical analysis of the numerous allusions to the mineral resources of India, which are to be found in writings belonging to the period extending from the earliest times of which any records are extant up to the close of the eighteenth century.

Much has been done in the matter, however, by Mr. King, in his several masterly works on precious stones; but the mode of treatment here adopted differs from his in being primarily based on our present knowledge of the mineral resources of India. Had all the data now available on that subject been before him there would have been little new for discussion in such a Paper as this.

The facilities which I have enjoyed for consulting authorities, both in Calcutta and here in Dublin, in the rich treasury of rare volumes in the library of Trinity College, have enabled me to present a much longer list of writers than would have been possible had the field of research been limited to but one of these sources.

Two methods of employing the collected facts were open to me—either to arrange them under subjects or under authors' names: the latter, as it presents a general view of the development and increase of knowledge, has been adopted. It is not without the manifest objection that the same subject crops up again and again in a disjointed manner; but if the facts had been arranged under the heading of subjects, the communication would have taken the form of a treatise on Economic Geology of India, which would scarcely be a suitable one for such an occasion as the present.

The earliest traders in Indian commodities, of whose proceedings we have any record, were the Egyptians. According to Le Normant,[1] the bas-reliefs of the temple of Deir-el-Bahari at Thebes represent the conquest of the land of Pun under Hatasu. "In the abundant booty, loading the vessels of Pharaoh for conveyance to the land of Egpyt, appear a great many Indian animals and products not indigenous to the soil of Yemen—elephants' teeth, gold, precious stones, sandal-wood, and monkeys."

Again,[2] "The labours of M. de Bohlem (Das Alte. Indien, vol. i. p. 42), confirming those of Heeren, and in their turn confirmed by those of Lassen (Ind. Alt. ii. p. 580), have established the existence of a maritime commerce between India and Arabia from the very earliest period of the annals of humanity." The

[1] Hist. Anc. de L'Orient—English edition, vol. ii. p. 299.

[2] *l. c.* p. 301.

principal commodities imported from India were gold, tin, precious stones, ivory, &c.

In the Mosaic period (1491–1450, B.C.), too, precious stones, which were to a great extent a specialty of India and the neighbouring countries, appear to have been well known, and were already highly valued. It is probable that some of the stones in the breastplate of the high priest may have come from the far East. The emerald, however, if then known, was probably derived from a mine in Egypt, to which reference will be made hereafter. At the same time there are grounds for believing that the word so rendered (Exod. xxviii. 18; Ezek. xxviii. 13) may not be correctly translated.

The next traders in Indian products were the Phœnicians, who for a time carried on their commerce with the ports of Aden, Cana, Haran, Yemen, and Muza, to which the commodities of India were brought for exchange by Arabian, and possibly Indian and Cingalese, ships.

Somewhere about 1015 B.C., Solomon joined Hiram, King of Tyre, in a nautical and commercial venture of a more ambitious nature than had previously been attempted, "For the king had at sea a navy of Tharshish with the navy of Hiram: once in three years came the navy of Tharshish, bringing gold and silver, ivory, apes, and peacocks."[1]

These ships were the first which had ever doubled the southern parts of Arabia and then sailed straight for India. The first port in that country of which we have any mention is Ophir. The vessels were built of timber from Judea, at Elath and Eziongeber, and they were manned by Phœnicians. They were called "ships of Tharshish," because they were of the same form and build as those which had previously been employed in the trade to Tharshish, situated, as is now generally known, in the south of Spain.

It is needless, perhaps, to discuss here the many views which have been put forward as to the identity of Ophir. Lassen[2] says it was on the site of Abhira, on the western coast, adjoining the province of Guzerat. Others locate it in Ceylon; but General

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[1] I. Kings, x. 22; also see ix. 28., &c.

[2] Indisch. Alter., vol. ii. pp. 584–592.

Cunningham's researches place it also in the Gulf of Cambay. The name Ophir, or Sophir, he identifies with *Sauvira*, a name derived from that of the ber-tree (*Zizyphus jujuba*), which is plentiful in that region.[1]

Since gold, silver, ivory, apes, and peacocks are productions of India—and the Hebrew name for the last is derived from *tukki*, an Indian word—there is internal evidence that Ophir was situated in that country. It is not likely to have been in the more Eastern, Burmese, or Malayan countries, where, it must be admitted, the same commodities might have been obtained.[2]

Passing the notices of precious stones to be found in the biblical books written during the course of the next five centuries, we find that Herodotus (fifth century B.C.) gives us some insight into the nature and extent of certain Indian mineral productions. Babylon obtained precious stones and dogs (probably Thibetan mastiffs) from India.[3]

In the enumeration of the nations and tribes which paid tribute to the Persian monarch, Darius, the Indians alone, we are told, paid in gold, all the others paying in silver. The amount of this gold was 360 Eubœic talents = £1,290,000. Herodotus pointedly, moreover, speaks of India as being "rich in gold";[4] and he relates the famous and widespread fable of the gold-digging ants, the origin of which has been fully ascertained, as I have already described in our Journal.[5] I shall only add now that the "horns of the gold-digging ants," referred to by Pliny and others, were, probably, simply samples of the ordinary pickaxes used by the miners. In Ladakh, and, probably, also in Thibet, these implements are made of the horns of wild sheep, mounted on handles of wood.

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[1] Anc. Geog. of India, pp. 496–7; and 560–62.

[2] Mr. Eastwick estimates that the gold which reached Solomon by way of the Red Sea amounted to 3,330,000 lbs. in weight, or 160 millions sterling. In his Paper entitled, "Gold in India," it may be added, he is inclined to locate Ophir in the Malabar country, in the neighbourhood of the gold-bearing regions of Southern India.

[3] Herodotus, i., 192.

[4] *l. c.* iii. 106.

[5] Vol v., p. 278. The fable has been shown by Sir Henry Rawlinsonand Dr. Schiern to have originated in the peculiar customs of the Thibetan gold miners, which would appear to be the same at present as they were in the time of Herodotus. The name "Ant" gold was possibly first given to the fragments of gold dust brought from Thibet on account of their shape and size.

The portion of India conquered by Darius was probably situated chiefly to the north-west of the Indus. The Indus itself, as well as some of its tributaries, is known to be auriferous.

Many commentators on the above and other references by subsequent authors to the existence of gold (and silver), as indigenous products of India, object that mines of these metals are or were not known to exist in India. Thus Lassen says: "If the ancients speak of abundant gold in India, it is either only a false amplification of the early and true account of Northern India, the country of the Dards, between Kashmir and the Upper Indus, or a false conclusion, from the fact that the Indians used much gold for ornaments and other purposes." Heeren, like Lassen, alludes doubtfully to Pliny's statement (*vide postea*) as to the existence of abundant gold and silver mines in the country of the Nareæ: he attributes the quantity of gold which must have been in Ancient India to commerce with other gold-producing countries, namely, Thibet and Burmah. He even suggests[1] that African gold found its way to India in early as well as it is known to have done in later times.

Our most recent knowledge of India, however, affords evidence that the amount of gold derived from indigenous sources must have been very considerable before the alluvial deposits were exhausted of their gold throughout wide regions.

When it is remembered that about 80 per cent. of the gold raised throughout the world is from alluvial washings, and when this fact is considered in connexion with the reflection that wide tracts in Australia and America, formerly richly productive, are now deserted, being covered with exhausted tailings, it can be conceived how these regions in India, and there are very many of them, which are known to be auriferous, may, in the lapse of time, after yielding large supplies of gold, have become too exhausted to be of much present consideration.

More than this, however: recent explorations have confirmed the fact, often previously asserted, that in Southern India there are indications of extended mining operations having been carried on there.

Evidence exists of the most conclusive kind of large quantities

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[1] Asiatic Nations, vol. iii. pp. 408–9.

of gold having been amassed by Indian monarchs, who accepted a revenue in gold dust only, from certain sections of their subjects, who were consequently compelled to spend several months of every year washing for it in the rivers.

The already-quoted facts taken from the pages of the Bible and Herodotus must be accepted as evidence that gold was an export from India, and that to so large an extent, that the suggestion that it was first imported may be safely rejected. A large amount, very probably, reached Northern India in the course of trade from Thibet; but it is incredible that the vast stores which, as will be shown on a future page, were in the possession of the princes of Southern India about 600 years ago, was, to any considerable extent, derived from extraneous sources.

Much uncertainty exists as to the date of the famous Indian epic known as the Ramayana. By Wilson, however, it is supposed to have been written about 300 B.C.; but it refers to a time probably contemporaneous with Solomon. It represents India as abounding at that early period in wealth, which we cannot but conclude was mainly of indigenous origin. In the description of the capital town of Ajodhya, as quoted by Heeren,[1] we are told "it was filled with merchants and artificers of all kinds; gold, precious stones, and jewels were there found in abundance; everyone wore costly garments, bracelets, and necklaces." Again, "The present made to *Sita* consisted of a whole measure of gold pieces and a vast quantity of the same precious metal in ingots: golden chariots, golden trappings for elephants and horses, and golden bells are also noticed as articles of luxury and magnificence."

The *Indika*, by Ktesias, the Knidan (398 B.C.) was the first regular Greek treatise on India. The fragments of it which have been preserved by Photios and other writers have recently been brought together and carefully annotated by Mr. M'Crindle, to whose work I am indebted for the following extracts bearing upon our subject. Ktesias's knowledge of India was all derived at second-hand from persons he came in contact with at the Persian Court, where he resided under Darius and his successor, Artaxerxes Memnon.

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[1] Asiatic Nations, vol. III., chap. ii. p. 355.

Ktesias informs us that there is a lake in the country of the Pygmies upon the surface of which oil is produced. The Pygmies are described as being covered over with long hair. A tribe corresponding to this description has been reported to exist in Upper Burmah, and there also are the only largely productive petroleum deposits, which, moreover, we know to have been worked since the earliest times.[1] Silver also was and is found in this region.

This report, however, it should be clearly understood, requires very distinct confirmation before it can be accepted. It is probably merely a fable; but the existence of sources of rock-oil and silver in Upper Burmah is noteworthy, no other region being known to produce both, though silver is found in many localities in India, and rock-oil in Assam and the Punjab.

The elektron or amber of Ktesias, a product of trees, was certainly *shellac*, and the insects found with it, which yielded a red dye, were lac insects. As, therefore, this amber does not properly belong to our subject, I shall say no more about it at present.

Gold, we are told, was only obtained on certain "high-towering mountains" inhabited by the griffins—a race of four-footed birds, about as large as wolves, having legs and claws like those of the lion, and covered all over the body with black feathers, except only on the breast, where they are red. Now, if we omit the word "birds" in the above, and for "feathers" read "hair," there is no difficulty in recognising the griffins as the Thibetan mastiffs, which are powerful, hairy, often black-and-tan-coloured dogs, specimens of which, by the way, appear to have been taken to the Persian Court as examples of the gold-digging ants, which were first described by Herodotus.[2] We may, I think, therefore, justly conclude that the locality referred to was situated in Thibet.

Gold was also said to be obtained from a spring, being drawn from it in earthen pitchers in which it congealed. This story is obviously founded on the casting of ingots; but I cannot see that

[1] Economic Geology of India, p. 138.

[2] Herodotus (i. 192) tells us, as pointed out by Le Normant, that India supplied Babylon with "precious stones and large dogs; and so great was the passion for the latter, that Tritantæchmes, Satrap of Babylon under the Achæmians, had set apart four cities or large villages, exempted from all other taxes, on condition of maintaining his dogs."—Manual of the Ancient History of the East, vol. i. p. 496.

Lassen's view, that it shows that the Indians knew how to extract gold from *ores*, follows, since it may merely refer to the melting of alluvial gold dust.

Silver is said to occur also in the above-mentioned country of the Pygmies, upon which Lassen remarks that silver is only known to occur in Ajmir. It has, however, a much wider distribution, as I have shown in my "Economic Geology"; but the only region in which it is regularly produced at present is Upper Burmah.[1]

Iron is said to be found in the same spring or fountain as the gold; and Ktesias had two swords, made of Indian iron, given to him respectively by the King of Persia and his mother. This iron consisted, I believe, of ingots of *wootz* or cast-steel, from which Damascus blades have been made since time immemorial.[2] The power of iron to ward off thunderstorms, which is referred to by Ktesias, suggests rather an early knowledge of the use of lightning conductors than of the properties of the magnet, which is the explanation offered by Baehr.

The *Pantarba* is a kind of stone which, when thrown into the water, had the power of drawing together other stones of various colours to the number of 77. It has been suggested by Count Von Veltheim that this was some kind of opal, which, on being put into water, exhibited a rich play of colours. Upon this I can offer no opinion: no more probable supposition suggests itself to my mind.

The sardine stone, the onyx, and other seal stones, are said to be found in certain high mountains. There is no further indication of locality. Possibly, Oujein, in Malwa, or some of the other places where mines of Chalcedonic minerals occur, was intended.

Evidence of various kinds exists that in the time of the Indian monarch, Asoka, about 300 B.C., the mineral resources of India were well known and were largely availed of. Stone architecture on a magnificent scale, which is still extant, bears testimony to the skill of the Buddhist stone-masons of a still earlier period. The elaborate carvings on some of these prove the excellence of the tools which were employed; probably they were made of Indian steel or *wootz*. The famous Asoka monoliths of a later date, from 35 to

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[1] Economic Geology, p. 234.

[2] The name *wootz*, according to Lassen, Indisch. Alt. (i. p. 239), is derived from the Sanskrit *vag'ra*, from two words signifying diamond and thunderbolt.

40 feet long, and about as many tons in weight, are, in their way too, remarkable, though not exhibiting such ornate designs.

In B.C. 307, according to the *Mahawanso*,[1] the King of Ceylon (or Lanka), Dewananpiatisso, was installed, and shortly afterwards he sent an embassy to Asoka at Palibothra, the presents consisting of sapphires, lapis-lazuli, rubies, and eight varieties of pearls, which, we are told, rose miraculously from the earth and sea respectively on the auspicious occasion. Asoka's return-gift consisted of golden and other ornaments, and as an especial rarity, "costly hand-towels, which to the last moment they are used (are cleansed by being passed through the fire) without being washed."

Now, with reference to the above, I venture to think that the translator has made a mistake as regards lapis-lazuli. It has never been known to be a product of Ceylon. The word possibly means either the asteria (or star sapphire), or another blue mineral called iolite (or dichroite), both of which occur in Ceylon. In this connexion it may be interesting to note that, in some excavations made recently on the supposed site of Asoka's throne,[2] there were obtained sapphires and emeralds, mostly broken into splinters, two pebbles of iolite, some beads of lapis-lazuli, coral, &c., and some imitation emeralds, made of glass. Lapis-lazuli, therefore, was possibly known in Asoka's time, but probably it did not come from Ceylon, but from the mines in Badakshan, to be mentioned hereafter.

The hand-towels were most likely made of woven asbestos, a substance which has long been known to occur in Kabul,[3] and may very possibly have reached India from thence.

The work by Megasthenes (302 B.C.), entitled τα ινδικα, no longer exists, except in fragments, which have been quoted by subsequent writers. These have recently been brought together by Mr. M'Crindle from the pages of Strabo, Pliny, Arrian, Diodorus, &c. It is probable that these fragments represent only a small portion of the whole work; but so far as they go, since the individual quotations by each of the authors are checked by those of the others, we are justified in the belief that the

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[1] A History of Ceylon for Twenty-four Centuries, from B.C. 543: translated by Turnour, p. 70.

[2] *Vide* Proc. As. Society, Bengal; May, 1881, p. 89.

[3] Economic Geology of India, p. 519.

general facts related are as they were originally stated by Megasthenes.

The first statement bearing on our subject is taken from Diodorus[1]:—

"And while the soil (of India) bears on its surface all kinds of fruits which are known to cultivation, it has also under ground numerous veins of all sorts of metals, for it contains much gold and silver, and copper and iron in no small quantity, and even tin and other metals, which are employed in making articles of use and ornament, as well as the implements and accoutrements of war."

Upon this I shall only here remark that the item of greatest interest is the tin. Even in Homeric times reference to this metal as coming from India is to be found in conjunction with the mention of *elephas* or ivory. The Greek name for it, *kassiteros*, is moreover said to be derived from the Sanskrit, *kastira*. That India produced tin in sufficient quantities for exportation is, I believe, most improbable. The tin which she did export probably came to the Indian ports from the Malayan countries or Tenasserim.

The fable of the gold-digging ants, already alluded to as having been related by Herodotus, is quoted by Strabo and Arrian from Megasthenes. Arrian further also refers to the account by Nearchos,[2] who says that "he had not himself seen a specimen of the sort of ant which other writers declare to exist in India, though he had seen many skins of them which had been brought into the Makedonian camp."[3] But Megasthenes avers that the tradition about the ants is strictly true—that they are gold-diggers, not for the sake of the gold itself, but because by instinct they burrow holes in the earth to lie in, just as the tiny ants of our own country dig little holes for themselves; only those in India being larger than foxes, make their burrows proportionately larger. But the ground is impregnated with gold, and the Indians thence obtain their gold. Now, Megasthenes writes what he had heard from hearsay, and as I have no more exact information to give, I willingly dismiss the subject of the ant."

[1] Ancient India, p. 31. [2] M'Crindle's Arrian, p. 217.

[3] These I believe to have been skins of the Thibetan mastiffs (or griffins), which, I understand, are still brought to India for sale.

Pliny, in his list of the Indian Races, which is believed to have been mostly borrowed from Megasthenes, says:—"Next follow the Nareæ, enclosed by the loftiest of Indian mountains, Capitalia. The inhabitants on the other side of this mountain work extensive mines of gold and silver." Capitalia may certainly be identified with Mount Abu; and although the highest authorities are divided as to the identity of the Nareæ, the mention of mines of gold and silver compels me to believe that the Nairs of Malabar were intended, as in Malabar and the neighbouring regions are situated not only the ancient gold mines which have attracted so much notice of late years, but there are also enormous ancient mines in the districts of Kadapah and Karnul from whence argentiferous galena appears to have been extracted, and from this ore silver was, very probably, obtained.[1]

In another passage in this list of Pliny we find the following statement:—"Gold is very abundant among the Dardæ and silver among the Setæ." On this Mr. M'Crindle remarks that the Setæ are the Sata or Sataka of Sanskrit geography, which locates them in the neighbourhood of the Daradas. I was inclined to believe that the country of the Setæ may have been the Wazir-i-rupi, or silver country of the Wazirs, *i.e.* Kulu, where argentiferous galenas undoubtedly do occur.

Colonel Yule identifies them, however, with the Sanskrit *Sekas*, and he places them on the Bannas, about Jhajpur, south-east from Ajmir. There are extensive ancient mines from which galena was obtained near the Taragarh hill in Ajmir; but, so far as I can ascertain, there is no record of their having produced silver. Galena, known to contain silver, appears to have been mined for at Jodawas in Alwar, and at Jawàr or Zawar in Udepur, but this latter locality was chiefly remarkable, indeed unique in India, for producing zinc.[2]

Further on, in Pliny's enumeration above alluded to, we meet the following passage:—"Beyond the mouth of the Indus are

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[1] *Vide* Economic Geology of India, p. 232.

[2] Todd (Rajasthan, p. 12, 504), has described this as being a tin mine, an error which has misled Lassen (Indisch. Alt., vol. i. p. 239), who states that the large production from this mine may account for the fact that the Indian name of tin, already alluded to on a previous page, was at so early a period spread throughout the western world.

Chrysæ and Argyræ, rich, as I believe, in metals. For I cannot readily believe, what is asserted by some writers, that their soil is impregnated with gold and silver. At a distance of twenty miles from these lies Crocala." This last, according to Mr. M'Crindle, is identified with Karkalla, the district which includes Karachi; but Colonel Yule identifies the former two localities with Burma and Arakan, as will be mentioned below in connexion with Ptolomey's reference to the same subject.

About the year 30 B.C. Dionysius Perigetes, in his "Oikoumenes Perithesis," gives a rough indication of the position of the region from whence the diamonds which at that time found their way to Europe were derived.[1] The *adamas*, he states, together with beryl, green jasper, topaz, and amethyst, were found in the river beds of the country lying to the east of Mount Parapamissus (*i. e.* the Hindu Kush) and Ariana. Although some doubt may be felt in this instance as to the true meaning of the term *adamas*, its applicability to the diamond, when used by Manilius a few years later, is indisputable. This latter author flourished during the Augustan age (B.C. 31 to A.D. 14), but the exact date of his poem is not known.

PLINY, A.D. 77.—In his Historia Naturalis, the industrious compiler Pliny has given an extraordinary amount of information regarding precious stones and metals, a large proportion of them being of Indian origin.

Reference has already been made to those passages which appear to have been derived from the older authors, more particularly to those referring to gold. A locality, namely the Ganges, mentioned by Pliny (B. xxxiii., c. 21), may, perhaps, refer to known sources of the precious metal in the tributaries of the Upper Ganges. His remarks on the quantity of gold in India (B. xxxiii., c. 21) are full of interest.

Regarding iron, he says the best is made by the Seres; some authors suppose them to have been an Indian tribe inhabiting Sarhind, the modern Umbala District, but the balance of evidence is certainly in favour of their having been Chinese. The next quality is from Parthia. Elsewhere he says (B. xii. c. 8) that the Romans obtained steel, together with pearls, at Cape Comorin.

[1] *Vide* Latin Version, vv. 315 and 1107.

His account of the Murrhine on the whole bears out the view as to its nature, stated below on page 89, save that he records (B. xxxvii. c. 7) that "a person of consular rank, who some years ago used to drink out of this cup, grew so passionately fond of it as to gnaw its edges"—a fact not consistent with it being a substance having the hardness of the Chalcedonic minerals.

Regarding amber, he quotes the account by Ktesias, which, as has been shown, refers to shellac, and alludes to the fable of amber being produced from the tears of the meleagrides (guinea-fowl). Another statement of his which I cannot explain is, that the Indians polish amber by boiling it in the grease of a sucking pig.

Adamas.—Under this head the diamond appears to have been included, together with some other stones. "It is," he says (B. xxxvii. c. 15), "the substance that possesses the greatest value, not only among the precious stones, but of all human possessions, a mineral which for a long time was known to kings only, and to very few of them." Where, however, he refers to its hexangular and hexahedral form, he appears to have been alluding to some other mineral; but his mention of splinters as being used by engravers of other stones again points to the true diamond. He says it could only be broken after being steeped in the blood of a he-goat.

Smaragdus.—Twelve varieties are mentioned (B. xxxvii., caps. 16, 17). Some of these may have been emeralds, especially those of the third rank, which are said to have come from Egypt. This locality is considered to have been Mount Zalora, in Upper Egypt, which still produces emeralds, and was probably the only locality for them known by the ancients. With reference to some of the other varieties, I feel no little confidence in suggesting that they may have been jade, but this mineral is also included in his account of *Jaspis.*

Beryls are said to be found in India, and rarely elsewhere (B. xxxvii. c. 20). It is certainly true that they do occur in India, but I am unaware of their being now highly esteemed by the natives, as appears to have been the case in Pliny's time.

Opals, according to Pliny, were alone produced in India. I am not aware of any known source of precious opal in India. His reference is therefore, probably, to some of the common varieties.

Want of space prevents me from further analyzing Pliny's

catalogue, the more particularly as it does not add much to what is elsewhere given on previous pages.

THE PERIPLUS OF THE ERYTHRÆAN SEA (*Circa*, A.D. 80–89?)—The author of this work, a Greek merchant, resident in Egypt, is not known to us by name. His statements of the Indian export and import trade are given with a great deal of method and obvious accuracy. The following extracts are from Mr. M'Crindle's translation. The principal ports mentioned are Barugaza, the modern Bharoch, on the Narbada; Barbarikon, on the Indus; Mouziris (Mangalore), and Nilkunda (south of Mangalore), both the last being on the coast of Malabar. First, as regards the exports: Indian iron and sword blades were exported from Arabia to Adouli in Africa. Indian iron is mentioned in the Pandects as an article of commerce, and the Arabian poets celebrate swords of Indian steel—as well they might, since the material of the famous Damascus blades was "wootz," which was manufactured in an obscure village in the Hyderabad territory.[1]

From the ports of Mouziris and Nilkunda gems in great variety were exported; but these, it is expressly stated, were not produced in India, but were brought from Taprobane or Ceylon. They probably consisted of the varieties of what we now call corundum, viz., sapphire, ruby, &c.

Separately, the Αδάμας is mentioned as being sent from these ports, and it seems probable that under this title we may understand that diamonds, the production of Indian mines, are referred to.

From Barbarikon, on the Indus, a stone called καλλεανὸς was exported. It has been suggested that gold stone or chrysolite was indicated by this name. I cannot think that this is likely to be correct. Chrysolite of value is not, so far as we know, a product of that region: more probably, as has been suggested by Dana, it was turquoise, or an allied mineral now called callianite. If this identification be correct, it probably came through Afghanistan from Persia—the most famous known source of it being at Amsar, near Nishapur in Khorassan. Its occurrence anywhere nearer is extremely doubtful.[2]

From Barugaza to Egypt vast quantities of 'Ονυχινὴ were

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[1] *Vide* Economic Geology, p. 340.

[2] Economic Geology, p. 435.

exported. They reached the seaport from Ozene and Paithana, the modern Ujein in Malwa, and Paithan in Hyderabad. These are still known as the principal sources, among many, where pebbles of onyx and other Chalcedonic minerals are obtained from the detritus of the Deccan basalt.[1] The famous Μουρρίνη, which fetched extravagant prices[2] in the Roman markets, was also obtained in Ozene and exported from Barugaza.

Regarding the identity of this substance, Herman Müller, as quoted by Mr. M'Crindle, remarks:—"Six hundred writers emulously applying themselves to explain what had the best claim to be considered the *Murrha* of the ancients, have advanced the most conflicting opinions. Now it is pretty well settled that the Murrhine vases were made of that stone which is called in German *flusspath* (*spato fluore*"). In spite of a desire not to augment this intolerable number of opinions, I must register an objection to this judicial decision of Professor Müller. Fluor spar happens to be, though so common a mineral in other countries, of the very greatest rarity in India, and there is no record of its occurrence in the Deccan basalts. It is, moreover, a mineral which, while it is susceptible of being made into ornamental objects, is, from its softness, easily injured by wear and tear, and therefore possesses little durability.

On the other hand, at Ujein, a great variety of Chalcedonic minerals are found, and I therefore prefer to follow those of the six hundred writers who have identified one or other of its varieties with the ancient murrha. At the present day cups and vases of carnelian, agate, &c., are obtainable in Bombay; and I think it most improbable that the modern *Akiks*, or lapidaries, who are the direct descendants of those who made the murrhine cups 2000 years ago, ever saw, much less worked, the mineral called fluor spar.

Another argument in support of this identification has been urged by some writers: it is that stone cups and vases, and fragments of them which have been obtained in excavations at Rome, have, on examination, proved to be of this material. None of fluor spar are recorded.

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[1] Economic Geology of India, p. 502, where numerous references and a full account of the trade will be found.

[2] Nero gave for one 300 talents, =£58,125. They were first seen at Rome in the triumphal procession of Pompey.

The Σάπφειρος was, we are told, exported from Barbarikon. If this were the true sapphire of modern times, its export from the most northern port, and, therefore, furthest from the recognised sources of the stone, would in itself be difficult to explain. It has been, however, clearly shown by King [Precious Stones] and Dana [Mineralogy] that the Σάπφειρος of Theophrastus, Pliny, and Isidorus, &c., was what we now call lapis-lazuli. For Pliny says, "*Sappheiros cæruleus est cum purpura, habens aureos sparsos.*" Now lapis-lazuli is characterised by having scattered through the blue mass small crystalline particles of golden-coloured iron pyrites.

As further evidence in favour of this interpretation, there is the fact that there are very ancient mines of lapis-lazuli at Firgamu in Badakshan (not Beluchistan, as has been incorrectly stated by some writers), and it might very easily have been brought by caravans through Afghanistan to Barbarikon. The mines alluded to are described by Wood in the account of his journey to the Oxus, and both Marco Polo and Tavernier refer to the occurrence of the mineral in that region.

Captain Hutton, in 1841, found it on sale at Kandahar. He mentions several places in Afghanistan where it was said to occur.[1]

The Υάκινθος, on the other hand, which was exported from the southern ports Mouziris and Nilkunda, is thought by some to have been the sapphire, as also was the hyacinthus of Pliny (xxxvii. 44), and its variety the asteria (*id.* xxxvii. 49). The *yakut*, as the name is now understood in India, is either a ruby, or the inferior spinel (more properly called *laal*), or even a garnet. According to Salmasius, quoted by Mr. M'Crindle, the Υακινθος is the ruby, while according to Solinus it would appear to be the amethyst. This is a point on which Indian geology throws no certain light, as neither rubies nor sapphires appear to have been indigenous products.[2]

In the Persian work on precious stones quoted hereafter, it will be seen that in the thirteenth century the same generic name was applied to the ruby, sapphire, and other varieties of corundum.

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[1] *Vide* Economic Geology of India, p. 528.

[2] It should be stated that there have been recent discoveries of sapphires in the Himalayas, but there is no evidence that they were ever found there before.

With reference to the imports which are of interest as indicating the requirements, if not of the whole of India, at least of that portion of Western India into which they were carried, we find the following enumeration:—

Silver: Costly plate, from Egypt to Barugaza.
Gold and silver coins, from Egypt to Barugaza.
Gold bullion, from Arabia to Barugaza.
Arsenic, from Egypt to Mouziris and Nilkunda.
Tin, from Egypt to Mouziris and Barugaza.
Lead, from Egypt to Mouziris and Barugaza.
Antimony sulphide, from Egypt to Mouziris and Barugaza.
Copper, from Egypt to Mouziris and Barugaza.

The import of silver plate at this early period is remarkable. Whether it has been kept up in modern times, so far as the requirements of the natives are concerned, I cannot say, but the other substances are still largely imported. In four years recently, for instance, upwards of 200 tons of arsenic, in the forms of white arsenic, orpiment, and realgar, were imported; and the antimony sulphide, called *surma* by the natives of India, is largely used for anointing the eyes.

Χρυσολιθος was also exported from Egypt to all four ports. It appears to be tolerably clear that this mineral was not our modern chrysolite, but was the topaz, while the topazion of Pliny was in part at least chrysolite, as he says it yielded to the file and wore with use; but his mention of a statue, 4 cubits high, which was made of it, indicates a crystal of a size quite unheard of: probably this was either beryl or jade.

PTOLOMEY (A.D. 140–160). *Diamonds.*—The *Adamas* river of Ptolomey, according to Lassen's analysis of the data, was not identical with the Mahanadi, as I have suggested in my "Economic Geology,"[1] but with the Subanrikha, which is, however, so far as we know, not a diamond-bearing river, nor does it at any part of its course traverse rocks of the age of those which contain the matrix of the diamond in other parts of India. This *Adamas* river was separated from the Mahnada (*i.e.* Mahanadi) by the Tyndis and Dosaron; the latter, according to Lassen, taking its rise in the country of Kokkonaga (*i.e.* Chutia Nagpur), and to which the chief town, Dosara (the modern Doesa), gave its name. But,

[1] Economic Geology, p. 30.

according to this view, the Dosaron must have been identical with the modern Brahmini, which, in that portion of its course called the Sunk (or Koel), included a diamond locality. I cannot regard this identification as satisfactory, as it does not account for the Tyndis intervening between the Dosaron and Mahnada, since, as a matter of fact, the Brahmini and Mahanadi are confluent at their mouths.

Lassen, however, identifies the Dosaron with the Baiturnee, and the Tyndis with the Brahmini. This destroys the force of his remark as to the origin of the name of the former, since at its nearest point it is many miles distant from Doesa.

Another locality of Ptolomey's, said to be situated on the Ganges, in the country of the Sabaræ, may, perhaps, be identical with Tavernier's Soumelpour on the Koel; it was situated some miles distant from the Ganges. Wherever it was, it produced most diamonds.

A third locality mentioned by Ptolomey has been variously identified with Sambalpur and Weiragarh[1] in West Gondwana, the position of which last was not correctly known to either Ritter or Lassen, though the fact of the existence of diamond mines there had been recorded by Ferishta and Abdul Fazl.

Ptolomey stated that Ceylon produced the beryl, hyacinth (? = sapphire), and all sorts of metals; the last is, however, not the case, Ceylon being rather poor in metallic ores.

Under the name Bathana, a source of the onyx is mentioned by Ptolomey; this appears to have been a well-known locality at Paithan on the Godaveri, which was alluded to as Plithana by the author of the Periplus.

The sardonyx mines of Ptolomey are probably identical with the famous carnelian and agate mines of Rajpipla, or rather, as it should be called, Ratanpur.

The loadstone rocks of India, which attracted so much notice by several early writers, were known to Ptolomey; they may possibly be identified with certain hill ranges in Southern India which mainly consist of magnetic iron.[2] Early writers connected their presence with the fact that many of the vessels and boats engaged in the Indian coasting trade contained no iron in their construction,

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[1] See Economic Geology of India, p. 37.

[2] *l. c.* p. 335.

and hence probably arose the well-known fable about the injury to shipping caused by the loadstone rocks. The surf boats, however, have no iron in their construction, simply because bolts or nails would render them too rigid; nor have the vessels of the Laccadives and Maldives, because iron ores do not occur in coral islands.

The identity of *Argyre* (where, according to Ptolomey, there were mines of silver), *Chrysé chersonesus*, *Chryse chora*, and *Chalkitis* have recently been discussed by Colonel Yule.[1]

The first he proves to be Arakan, where, however, there are no silver mines; and considering the geological structure of the country, it is almost certain there never were any. I have been recently informed by General Sir Arthur Phayre that Argyre is probably a transliteration of an ancient Burmese name for Arakan. It seems likely, therefore, that it was from putting a Greek interpretation to this name that the story of the silver mines owed its origin. According to Colonel Yule, the Arabs probably adopted their ideas from the Ptolomaic charts. With regard to the other localities, he says, "The golden Chersonese is specifically the protuberant delta of the Irawadi, Pegu, the *Suvarna bhumi*, or golden land of Ancient India, whilst the golden region behind is Burma, the oldest province of which, above Ava, is still formally styled in State documents, *Sona paranta*, "Golden frontier." Ptolomey's *Chalkitis*, also, or copper region, approximates curiously to the *Tampa-dipa*, or Copper Island of the Burmese State phraseology, "a region which embraces Ava and the ancient capital Pagan."

These identifications remove from the region of probability what has sometimes been urged, that Argyre and Chryse were countries which supplied India with large quantities of silver and gold.

ARRIAN (*Circa*, A.D. 146.)—The first part of Arrian's Indika was founded on the works of Megasthenes and Eratosthenes, and the second on an account of the voyage made by Nearchos the Kretan from the Indus to the Pasitigris. The parts of this compilation which bear upon our present subject have already been anticipated in the description of Megesthenes' writings, and need not, therefore, be repeated.

The authors whom I have consulted with reference to the

[1] Proceedings of the Royal Geographical Society, 1882, p. 654.

Roman trade with India are: Robertson,[1] Renaud,[2] and Priaulx.[3] This trade, which succeeded that of the Greeks, came to an end in the sixth century. Besides what has already been independently quoted from the pages of Pliny and Ptolomey, there do not appear to be any records of much importance bearing upon the present subject.

An account of India, written for Palladius towards the close of the fourth or beginning of the fifth century, makes special reference to the loadstone rocks, possibly quoting from Ptolomey. In the fifth century Hierocles speaks of the Brahmins as being clothed in garments made from a soft and hairy filament obtained from stones. This, it seems most probable, owed its origin to some mistaken notion as to the origin of cotton rather than to the use of woven asbestos, as has been suggested.

Under the Emperor Justinian, in the sixth century, Cosmos (surnamed Indicopleustes), an Egyptian merchant, made several voyages to India, and recorded his experiences in a work called Christian Topography, in which some account of the export trade of India is given. He mentions how the Persians became rivals of the Romans at the Indian ports, and how the precious commodities were conveyed from thence up the Persian Gulf, and were distributed by means of the Euphrates and Tigris. Gradually the trade to Constantinople, the then seat of the Romans, was thus diverted.

Eighty years after the death of Justinian, Mahomet published his new religion, and it was not long before the Arabians spread themselves as conquerors over the countries adjoining their own, thence spreading by sea and land over an ever-widening area. To a great extent they wrested the Oriental trade from the Persians; they established a mart at Bussora, which speedily rose to an importance scarcely exceeded by that of Alexandria in the height of the Greek and Roman period. So little is known of the details of this trade, that there is only barely sufficient evidence for the

[1] Historical Disquisition concerning the Knowledge which the Ancients had of India. London: 1809.

[2] Relations Politiques et Commerciales de l'Empire Roman avec l'Asie Orientâle . . . pendant les cinque premiers siècles de l'ére Chrétienne. Jour. Asiatique, 6th ser., 1863, tome 1.

[3] "Apollonius of Tyana."

conclusion that, as regards the mineral productions, it did not differ materially from that which preceded it in the hands of other nationalities.

The most important work giving an account of India at about this period is the famous voyage by a Mahomedan traveller, with annotations by another, called Abu Seid al Hassan of Giraf.[1] Their account is confirmed by another Arabian called Massoudi, whose universal history bears the fantastic title, Meadows of Gold and Mines of Jewels.

The effect of this absorption of the trade of the Red Sea was to deprive the European nations of that highway of commerce, and the requirements of Europe had to be brought to Constantinople from India and China by long and tedious overland journeys, which became especially arduous during the Crusades. This state of things continued till the discovery by the Portuguese in the fifteenth century of the long sea passage round the Cape of Good Hope.

From various sources, however, we are enabled to pick up fragments of information referring to different centuries included in this interval. Thus a Sanskrit work called the Brhat Sanhita,[2] which, it is believed, was written in the sixth century, contains a very detailed account of diamonds, their varieties, qualities, and attributes. Of especial interest is a list of eight localities where diamonds were found. Most of these I have succeeded in identifying with sites where diamond mines are known to have been worked.[3] With regard to some of the localities, however, it is more than doubtful whether they ever produced diamonds.

The first Englishman who visited India appears to have been Sighelmas, Bishop of Shirburne, who was sent thither, in the year 883, by King Alfred, to visit the famous Christian named St. Thomas. This Bishop, we are told, made his journey in comfort, and brought back with him "many splendid exotic gems and spices, such as that country plentifully yielded"[4]—a fact in itself of no great importance, save that it is a link in the chain.

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[1] First translated in A.D. 1718 into French by M. Renaudot.

[2] Translated by Dr. Kern, Jour. Roy. Asiatic Society, vol. vii. N.S. 1875, p. 125.

[3] Economic Geology of India, p. 2.

[4] Recorded by William of Malmesburie in De Gestis regum Anglorum. Book ii. cap. iv. *Vide* Hakluyt's English Voyages.

Somewhere between the years 1067 and 1081 Marbodius wrote a poem entitled De Lapidibus Preciosis, in which he gave expression to the then prevailing ideas as to the sources and qualities of the diamond. Far India is recognised as its native place, and the use of splinters of it for engraving upon other gems is alluded to. Its hardness is said to yield to steeping in goat's blood—a fable already quoted from Pliny. How this idea originated it is not easy to say; possibly it may be connected with the sacrificial offerings which preceded the search for diamonds, as will be described on a future page.

In the eleventh century, according to Dr. Burnell, wealth must have abounded in Southern India, because it was then that the numerous *Sivoid* temples were built; and in the thirteenth century the great *Vishnu* temples were erected. Regarding the famous inscription on the Tanjore temple, he has written as follows:—

"The full importance in Indian history of Vera Cola's reign is only to be gathered from this inscription; but it contains other information also of great value. It proves, *e.g.*, that in the eleventh century gold was the most common precious metal in India, and stupendous quantities of it are mentioned here. Silver, on the other hand, is little mentioned; and it appears that the present state of things, which is exactly the reverse, was only brought about by the Portuguese in the sixteenth century.

"I submit that the great abundance of gold spoken of in the inscription can have arisen only from mines, and that in the terrible convulsions caused by the irruption of Moslem invaders from the north and Europeans from the west, the position of these gold-fields was lost sight of."

It has been remarked upon this, that[1] "the full significance of this statement as affecting Southern India can be understood only when taken in connexion with the large areas which are known to have been worked by the natives." It seems to leave little room for doubting that the reefs and soils when first opened up were extremely rich, and that the soils as we find them now have been impoverished by repeated washings.

"In the year 1293, Allahud-din, afterwards Emperor of Delhi,

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[1] Brough Smyth; Report of Gold Mines of South-East Wynaad, &c.

took the city of Deogarh, but the citadel still held out. Subsequently Allah raised the siege, on receiving a ransom, the amount of which may well appear incredible, 15,000 lbs. of pure gold, 175 lbs. of pearls, 50 lbs. of diamonds, and 25,000 lbs. of silver, being enumerated among the items. So much appears certain, that Allahu'd-din levied an enormous sum upon Deogarh, and that consequently it must at that time have been a very great city and rich emporium."[1]

It has been suggested that this wealth must have been acquired by working the ancient mines of Southern India.

MAHOMED BEN MANSUR (thirteenth century).—The remarkable Persian work on Precious Stones by this author was translated first into German by Joseph von Hammer.[2] The following facts are from an English version[3] :—

Diamond. — Seven kinds are recognized, namely, (1) white transparent; (2) the pharonic; (3) the olive-coloured, the white of which inclines to yellowish; (4) the red; (5) the green; (6) the black; (7) the fire-coloured.

In spite of this elaborate classification, Mahomed's knowledge of the *habitat* is very vague. He says :—" In the eastern parts of India is a deep ravine, inhabited by serpents, where diamonds are produced. Some people suppose that it is found in the *yakut* mines."

Here there is an obvious allusion to the diamond myth—to be described hereafter.

Corundum (Senbade), he says, quite correctly, is next in hardness to the diamond, and is of a reddish or bluish colour. The mines were situated in India, Zanzibar, Siwas, Kerman, Nubia, and Ethiopia. The best kinds were from Siwas and Nubia.

Yakut. — Under this title are included six classes: (1) red (*i.e.* ruby); (2) yellow (*i.e.* Oriental topaz); (3) black (*i.e.* pleonaste); (4) white (*i.e.* white sapphire); (5) green (*i.e.* Oriental emerald); (6) blue, or smoke-colour (*i.e.* sapphire). Of these classes sub-divisions into varieties are given. It is certainly a most remarkable fact that at so early a period the essential identity of these precious stones — a fact only comparatively

[1] A Hand-book for Madras. John Murray, 1859, p. 94.

[2] Mines de l'Orient, vol. vi.

[3] Asiatic Journal, vol. ix. 1820, p. 345.

recently ascertained by chemical examination — should have been known to the Persians. The hardness and other characters are correctly stated also by Mahomed. The locality of the principal mines is stated to be the island of Saharan, which is sixty-two farsanges in diameter, and lies forty farsanges behind the island of Ceylon. The *yakuts* are found there in a high mountain. This jumble is not easy to explain, the true locality being Ceylon itself, which is noted for its high mountains, culminating in Adam's Peak.

Another locality is also mentioned, Tara, near Cairo, where mines were discovered A.D. 1270.

A stone, called by Mahomed the *chamahen*, should come here, if, as is stated, it is next to the diamond in hardness; but this is inconsistent with another assertion that, when rubbed on a hard stone, it colours it red. When broken, it divides into branches. The most beautiful is blackish-red; it is found in the district of Karak. But for the first statement I should be inclined to identify this as jasper.

Spinel (Laal).—Of this there are four classes, namely, the red, yellow, violet, and green. Of the red there are eight varieties. Mahomed only mentions one mine, that in Badakshan, the capital of which, Balkh, gave origin to the term "Balas." His account, which is as follows, was unfortunately not available to me when giving a *précis* of information regarding the locality[1]:—"At the time of the caliphate of the Abbasides, a mountain at Chatlan was rent open by an earthquake, where there was found the *laal* of Badakshan, bedded in a white stone. It is very hard to polish, and it was a long time before it could be smoothed, till it was at length accomplished by means of the gold marcasite called *ebrendshe*. Smaller stones are found in the bed round a large one, like the seeds of a pomegranate. The miners call this bed of the Spinel *maal*. There were found in the mines first red, then yellow *laal*, and it belongs to the kinds of the *yakut*." The discovery of these mines by a landslip finds a parallel in a recent discovery of sapphires in the Himalayas.[2] The white stone which formed the matrix is probably limestone. Wood, in 1837, stated that the matrix was a red sandstone *or* a limestone impregnated with magnesia, but he did not personally visit the mine.

[1] Economic Geology, p. 430.

[2] Records of the General Survey of India, vol. xv., 1882, p. 138.

Turquoise (Firuse)—Obtained at Nishabar, Ghasna (? Ghuznee), Irak, Kerman, Chouresm, the first being the most valued. There is, therefore, no Indian locality: such seems to be still the case.

Talc (Šitarei semin = star of the earth)—Two kinds—one found in the air (? superficially), and the other in mines. Mahomed says —" artificial pearls are made from it, and it does not burn or calcine with fire. If you dissolve it and rub the limbs with it, it makes them fire proof. Talc can neither be pounded in mortars nor broken to pieces with hammers. The way to dissolve it is to boil it with beans; to wrap it then in a piece of linen. If dissolved talc is mixed with a little resin and saffron, and used as ink, it makes a gold ink, and, without saffron, silver ink."

Rock Crystal (Bellor).—Of this two kinds are mentioned, one being clear, and the other dark-yellowish. The added statement that they can be melted like glass, and then coloured so as to imitate the *yakut*, *laal*, or emerald, is unintelligible, since rock crystal by itself is a most infusible substance. Perhaps what is meant is, that siliceous sand was used in the manufacture of the glass or paste of which false stones were made.

Mahomed says that at Ghasna, there were four crystal vessels, each of which could contain two skins of water. He mentions that crystals of other minerals and wood (probably crystals of tourmaline) often occurred enclosed in the *bellor*. Some fanciers, we are told, prefer the Arabian to the Indian variety.

Amethyst (Dschemst)—Four kinds: (1) deep rose-colour and sky-blue; (2) pale rose-colour and deep azure; (3) pale rose-colour and sky-blue. It was much esteemed by the Arabs. Mahomed does not refer to its occurrence in India, but states that it was obtained near the village of Safwa, three days' journey from Medina. Wine drunk out of a goblet made of amethyst does not intoxicate, upon which Mahomed's translator remarks:—" This opinion was also current in Europe, and the name *dschem* or *dschemsshid* is connected with it. The Greek word αμεθυστος also means "unintoxicated," but it is originally derived from *dschemcst*, as the jasper from *jaschep;* hyacinth from *yakut;* emerald from *Semerrud;* pearls (Margarita) from *merwarid;* turquoise from *firuse;* lapis-lazuli from *ladschwerd;* sardonyx from *sard;* talc from *talk;* chalk from *kals.*"

Emerald (Semerrud).—Seven varieties or different shades are

recognised. The mine was situated on the border of Negroland, in Egyptian territory. The matrix of the gem was talc and red earth. It seems probable that this was the source of the emeralds which went to India, and also supplied the Greeks and Romans. A soap-green emerald was also found at Hedshas, in Arabia.

Owing to the fact that jade was not recognised as a distinct mineral until introduced into Europe from the New World, the older writers sometimes, on account of its hardness and transparency, spoke of it as emerald, while others applied to it the term jasper. There can be no doubt that jade is meant by the following, not jasper, as his translator has it:—

Jaschep, or *Nussz*.—Five kinds: (1) white and light; (2) whitish yellow; (3) black-green; (4) transparent black; (5) dust-colour.

Mahomed adds that in China they make false jaschep, which is distinguished by its smoky smell, and that there are two mines in China called respectively Ak-Kash which produces light, and Kut-Kash which produces dark jaschep. It is found on the frontiers of Kashgar, Kerman, and Arabia.

Kash is the name for jade current in Eastern Turkistan, and *su* or *zu* is the name by which it is known to the Chinese, who esteem it more highly than do the people of any other nation.[1]

Chrysolite? (Sheberdshed).—This is said by Mahomed to be obtained in the same mine as the emerald, of which it is a variety according to some authorities. If so, it cannot be what is now known as chrysolite, which is the transparent variety of olivine.

Mahomed mentions a number of other minerals, among them several ores. Of the magnet he says there are four kinds, namely, the iron, gold, silver, and tin, which attract these metals respectively; possibly by this it is meant to be conveyed that ores ascertained to contain these metals exhibited magnetic properties.

The following statements, regarding the knowledge possessed by the Persians of the relative specific gravities of some precious stones, are of interest:—

"Abu Rihan is said to have found by experiment that a muskal (= $1\frac{1}{2}$ drachms) of blue *yakut* (sapphire) is equal to five dank and a tissu of red *yakut* (ruby), or to five dank and two and

[1] Economic Geology, p. 516, *et. seq.*; and also p. 255 of this Paper.

a-half tissu of *laal* (spinel), and that four dank, minus a tissu of coral, are equal in size to four dank, minus two tissu of onyx and crystal. The mode of discovering the size and weight is the following:—A vessel is filled with water, and the stones thrown singly into the water; the quantity of water which is expelled from the vessel by means of each stone is equal to the room it occupies."

MARCO POLO.—A notable authority on the mineral production of India during this same thirteenth century is the famous Venetian traveller, Marco Polo. In reference to the diamond, he states that it was only obtained in what he designates as the kingdom of Mutfili—a name which has been identified by Colonel Yule with Motupalle, a still existing port in the Guntur District of Madras. The proper name of the kingdom was Telingana, which therefore included the so-called Golconda mines of the Kistna Valley; but Marco Polo extended to it that of the town or post which he visited. It is noteworthy, as testimony of an early trade, that Marco Polo states that "those diamonds brought to Europe are, as it were, the refuse of the finer stones, which go to the Great Kaan and the other kings and princes of India." He describes three methods as being followed in the search for diamonds:—

First: After the rains the beds of torrents from the mountains were searched; these localities were infested with venomous snakes.

Second: Pieces of meat were thrown down from the tops of mountains into inaccessible valleys; these pieces of meat were pounced upon and carried up to the tops of mountains by white eagles, and, when recovered, diamonds were found sticking to them. This story, made familiar to all by the travels of Sindbad the Sailor, is one of great antiquity. The earliest mention of it, according to Colonel Yule, is by St. Epiphanius, Bishop of Salamis, in Cyprus, who, in the fourth century, wrote a treatise on the twelve jewels in the breastplate of the High Priest. The tale, as told by him, however, refers to the jacinth, not to the diamond.

A list of the authors who have alluded to this tradition will be found in Colonel Yule's edition of Marco Polo.[1] Its origin, as

[1] Vol. ii. p. 298.

first suggested by me,[1] I shall discuss in connexion with the account given by Nicolo Conti.

Third: This method, which may be described as a corollary of the second, consisted in searching the birds' droppings and intestines for diamonds which they had swallowed with the meat.

Marco Polo, in various parts of his book, refers to other precious stones, especially to the Balas rubies and "azure" or lapis-lazuli of Badakshan. The value of the former was kept up by a limit being imposed by the king on the out-turn. The latter, he says, occurred in a vein like silver, and was the finest in the world.

In reference to gold and silver[2] there are several important facts recorded; among others, the enormous extent of the accumulation of gold in the treasuries of the princes of Southern India, upon which Colonel Yule remarks, after speaking of the spoil carried off by Allahud-din, that "some years later, Mahomed Tuglak loads two hundred elephants and several thousand bullocks with the precious spoil of a single temple." And a further statement, given on the authority of Wassaf, is, that "Kales Dewar, Raja of Malabar, about the year 1309, had accumulated 1200 crores of gold, *i.e.* 12,000 millions of dinars."[3]

Marco Polo distinctly mentions copper, gold, and silver as being imports into Malabar and Cambay from Eastern countries in his time.

FERISHTA.—Our next authority is the Indian historian, Ferishta, who wrote in 1425. What he says on the subject is chiefly of importance as confirming other evidence of the great wealth possessed by the princes of Southern India in the form of stores of precious stones and bullion. It has already been partly quoted on page 96. He refers to now long-deserted diamond mines in the Central Provinces of India,[4] which I have been able to identify as having been situated at Wairagarh, in the Central Provinces.

NICOLO CONTAI.—The last writer of what may be called the fabulous period, which closed with the fifteenth century—at least in so far as regards the diamond fable—was the Venetian, Nicolo Contai,

[1] Jour. As. Society, Bengal, vol. L. pt. ii. p. 31.
[2] *G.*, vol. ii. pp. 276, 284; *S.*, *ibid.* pp. 325 and 327.
[3] Marco Polo, vol. ii. p. 284, note 6.
[4] History. Ed. by J. Briggs. London: 1819, vol. ii. p. 261.

an account of whose voyage is given by Baptista Ramusio[1] in his book of Voyages and Travels, on the authority of Messer Pogio, Fiorentino. The locality where the diamonds were found was at Abnigaro, fifteen days' journey northwards from Bisnagar.[2] As to its identity I am not yet quite satisfied. We are told that the mountain which produced the diamonds was inaccessible, being infested with serpents, but was commanded by another mountain somewhat higher. "Here, at a certain period of the year, men bring oxen, which they drive to the top, and having cut them into pieces, cast the warm and bleeding fragments upon the summit by means of machines which they construct for the purpose. The diamonds stick to these pieces of flesh. Then come vultures and eagles flying to the spot, which seizing the meat for their food, fly away to places where they may be safe from the serpents. To these places the men afterwards come and collect the diamonds which have fallen from the flesh."

He then describes a different process, which is simply that of washing for diamonds in the beds of rivers. For as far back as we have any certain knowledge of them, the diamond miners have all belonged to one or other of the non-Aryan or aboriginal tribes, who regard the mines as being the special property of the bloodthirsty goddess, *Lakshmi*, whose cruel nature requires much propitiation.

To this day sacrificial offerings are made to her on the opening up of mines, of whatever sort, and occasionally the meat is placed on an altar-like scaffold; and in India, as a matter of course, vultures and kites, with other raptorial birds, would carry away and devour whatever portions of meat they could seize upon.

Out of this custom it seems to me most probable that the tradition grew which has now attained to such a respectable antiquity. Lookers-on, unacquainted with the semi-savage rites, regard them as essential parts of the search for diamonds.

UERTOMANNUS.—In the year 1503, Lewes Uertomannus, who is described as a Roman gentleman, travelled in Western and Southern India. The account of his travels contains some interesting parti-

[1] Delle Navigationi et Viaggi. Venice: 1613.

[2] These two names are so written in Ramusio's volume, but in a translation of the passage, published by the Hakluyt Society, they are given as Albenigaras and Bizengulia.

culars bearing on our present subject.[1] Of Cambaia he says (p. 381): "In this region is also a mountaine where the onyx stone, commonly called corneola, is founde, and not far from thence also another mountaine where the calcedony and diamant are founde." If by *diamant* the diamond is meant in this passage, the fact is noteworthy, as the Ponassa of Ptolomey is probably identical with the modern Ponassa in this region. At the same time a doubt must be expressed as to true diamonds having been ever found there. Further on our author says (p. 383): "Sixe miles from the city of Decan (? Bisnagar) is a mountaine where diamonds are digged. It is compassed with a wall and kept with a garrison."

Uertomannus mentions that two European dealers in precious stones, named respectively John Maria and Peter Antonie, resided at Calicut with the king's licence. They had acquired a fair diamond of 32 carats, worth 35,000 crowns, a pearl of 24 carats, and 2000 rubies, some of 1 carat, and some of $1\frac{1}{2}$ carats. On their attempting to depart secretly with their treasures to Cannanore, they were murdered by order of the king.

Under the heading, "Of the Diamondes of the Old Myne," our author says (p. 424):—"These diamondes are found in the first India, in a kingdom of the Morres, named Decan, from whence they are brought to other regions. There are also found other diamonds which are not so good, but somewhat whyte, and are called diamondes of the new myne, which is in the kingdom of Narsinga (Lower Kistna). They of the old mine are not pollyshed in India, but in other places. There are made lykewise in India false diamondes of rubies, topazes, and white sapphires, which appear to be fine, and are also found in the island of Zeilan (Ceylon). These stones differ in none other save that they have lost their natural colour." In another place he gives information as to the local prices of other precious stones, as rubies, spinel, sapphires, topaz, &c.

Next follow a group of authors, the accounts of whose travels are to be found in Baptista Ramusio's above-mentioned work. The first of them is Andrea Corsali, Fiorentino, whose letter,

[1] The History of Travel, &c., done into English from the original Latin. By R. Eden and R. Willes. Lond.: 1577.

addressed to Signor Guliano de Medici, Duca di Fiorenza, is dated Cochin, 6th January, 1515; it contains only a few unimportant facts bearing upon this subject.

Another of these authors is Ludovico Barthema, whose information is almost identical with that already quoted from Lewes Uertomannus. The precise date of Barthema's work I have been unable to ascertain.

From the book of Odarodo Barbosa, which refers apparently to a period about the year 1519, and to a voyage to India made by way of the Cape of Good Hope, we learn that at Bisnagar, *i. e.* Vijayanagar, jewels brought from Pegu and Ceylon were on sale in great abundance, as also were diamonds from Narsinga. This author gives also a full account of the values, &c., of a number of precious stones, namely, rubies, spinel, diamond, sapphire, topaz, turquoise, hyacinth, and emerald, and mentions the localities where they were obtained, but these details are too voluminous for reproduction here.

Garcias ab Horto.—Our next authority is Garcias ab Horto, a physician resident at Goa, who, in 1565, produced a work in Portuguese, containing a considerable amount of interesting and—much of it, though not all—obviously accurate information on our present subject.[1]

He tells us that there are two or three localities near Bisnagar (Vijayanagar) where diamonds were obtained, the industry being a considerable source of revenue to the king, as all stones above 30 mangelis (= 150 grs.?) became his property. Another mine also in the Decan produced excellent diamonds. It was situated in the lands of a native prince, near the territory of Imadixa (*i. e.* of Ahmed Shah?). This last was probably identical with the mine at Wairagarh, in the Central Provinces.

Garcias treats with scorn the old fable of the valley inhabited by serpents, and moreover points out that a Jesuit father, Francois de Tamara, who had repeated it, was therefore not worthy of credence, when he stated that diamonds were to be found in Brazil. The statement is of importance when it is remembered that the first diamond mines in Brazil were not opened up till 1728, or more than 160 years later. It may be added that the version of the fable just alluded to is that one where the serpents

[1] De Arom. et Simp. Historia, a Latin version by Clusius of Antwerp, 1567.

guard the jewels, and while they are engaged eating the meat thrown to them, the diamond-seekers are enabled to pick up the stones. Garcias speaks of several large diamonds which were known to exist in his time; two weighed 140 and 120 mangelis respectively (*i. e.* 700 and 600 grs.). Far exceeding these in size was one which he had heard of from a native who had seen it; it was said to be equal in size to a fowl's egg; it weighed 250 mangelis, or 1250 grs. This was, according to Tavernier, who wrote a century later, the form of the Great Mogul diamond when originally found. So that it seems quite possible that this casual notice by Garcias is the earliest mention of that famous stone.

Even in the time of Garcias it would seem that the tailings from earlier washings were sometimes rewashed with good results. He states that Lispor, in the Decan, was a principal mart for the sale. (Can this have been Vizapur or Bijapur?)

The geographical limits of Balaghat—a name used not only by Garcias, but also by some other writers—it would, probably, be impossible to closely define now. The name is still conserved as that of a particular district, but in early times it seems to have been applied to all the region in Southern India *above* the *Ghâts*, which was sometimes also called the Carnata, a name now, however, restricted to a district *below* the *Ghâts*.

With reference to other precious stones, Garcias states that a false smaragdas (emerald) was made of glass in Balaghat and Bisnagar. He distinguishes four varieties of ruby, as the true, carbuncle, balas, and spinel. Of sapphires he says two kinds were found in Calicut, Cannanore, and several places in Bisnagar. We have no knowledge of true sapphires ever having been obtained in these districts. Both hyacinth and garnet were found in Calicut and Cannanore, the latter being distributed throughout the whole of Cambay and Balaghat. Beryl was found in Cambay, Martaban, and Pegu, also in Ceylon: glasses and vases were made from it.

Garcias states that the Murrhine Cup was made of jasper; more correctly, perhaps, it was made of carnelian, as suggested on a previous page.

CÆSAR FREDERICK.—About the year 1567, a traveller named Cæsar Frederick[1] visited Western and Southern India. In a translation from his original account we find the following passage:—

[1] A translation of the account of his travels is given in Hakluyt's Voyages, vol. ii 1599, p. 213.

"The rubies, saphyres, and the spinels be gotten in the kingdom of Pegu. The diamants come from divers places, and I know but three sorts of them. That sort of diamants that is called *chiappe* cometh from Bezeneger. Those that be naturally pointed come from the land of Delly and Iawa (by which we must understand Borneo), but the diamants of Iawa are more waightie then the other. I could never understand from whence they that are called balassi come." The signification of *chiappe* is uncertain. The naturally-pointed stones probably came from Chutia Nagpur, or Kokrah, as it was then called, since Tavernier describes the stones from that region as being of this character, and it is believed that they were taken to Delhi. The term "balas" was applied to the spinel rubies from Badakshan. Possibly, it may have been used for those diamonds which had a roseate tinge.

On another page Frederick says:—"Also, five days' journey from Bezeneger, is the place where they get diamants. I was not there, but it was told me that it is a great place, compassed with a wall, and that they sell the earth within the wall for so much a squadron, and the limits are set how deepe or how low they shall digge. Those diamants that are of a certain size, and bigger then that size, are all kept for the king. It is many years agone since they got any there, for the troubles that have been in that kingdom."

FITCH AND NEWBERRY.—The famous traveller, Ralph Fitch, and his companion, Newberry, have left on record an account of their journeys in India, which refers to the years about 1583.[1] In reference to precious stones, the following are the most important passages:—Bellergan, the modern Belgaum, was said to be "a great market of diamants, rubies, sapphires, and many other *soft* (*i.e.* precious) stones." We are told that a jeweller named William Leades, who was one of their party, remained behind them in the service of the King of Cambay.

The next passage explains the use of the name Iawa, or Java, by Cæsar Frederick, and others:—"Laban (*i. e.* Borneo, the name being retained in Labuan) is an island among the Iawas, from whence come the diamants of the new water, and they find them in the rivers, for the king will not suffer them to digge the rock."

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[1] Hakluyt's English Voyages, vol. ii. 1599, p. 253.

Speaking of Patanaw (Patna) on the Ganges, below Banaras, it is said :—" Here at Patanaw they find gold in this manner. They digge deepe pits in the earth, and wash the earth in great bolles, and therein they find the gold, and they make the pits round about with brick, that the earth fall not in." I cannot but think that there is a mistake here, due to an account of gold-washing in the country to the south having been mixed up with a description of the method of sinking ordinary irrigation-wells in the neighbourhood of Patna. It is not likely that gold was ever found in sufficient quantity in the Gangetic alluvium, near Patna, to repay the cost of searching for it.

ABDUL FAZL.—Here we may turn aside again from European authorities to an Oriental writer, who, being a Mahomedan like the already quoted Ferishta, presents us with much more useful and matter-of-fact statements than are to be found in any works by Hindus. Abdul Fazl, the author of the Ain-i-Akbari, written in 1590, refers to the occurrence of and working for several minerals, especially diamonds, gold, and iron. The diamond mines at Beiragarh, in Gondwana, which he mentions as having been taken possession of by the ruler of Kullem, or Chanda, were probably the same as those already mentioned by Ferishta. In any case, it is certain that Beiragarh may be identified with the modern Wairagarh in the Central Provinces, where traces of the mines are still to be seen.

Gold was obtained, he says, in certain streams in Kashmir by pegging down, under water, the hairy skins of animals, which served to arrest the auriferous dust in its descent with the current. Long ago it was suggested that such skins were the origin of the idea of the skins of the gold-digging ants, mentioned by Nearchos and others, but the explanation given on a previous page is the more probable one. He alludes to the "steel" mines at Nirmal, which can be identified with a locality in Hyderabad, where a high quality of steel was prepared, most of which found its way to Persia, for manufacture into the Damascus swords, to which reference has already been made.

The enormous salt deposits of the Punjab are noticed by Abdul Fazl; and here may be quoted a passage from Strabo,[1] which should have appeared on a previous page :—

"It is said that in the territory of Sopeithes there is a moun-

[1] B. xv., chap. i. s. 30.

tain composed of fossil salt sufficient for the whole of India. Valuable mines also both of gold and silver are situated, it is said, not far off, among other mountains, according to the testimony of Gorgus, the miner of Alexandria." Since this salt crops out at the surface, and in Kohat especially, can be easily quarried, it is only natural that it should have attracted attention in the very earliest times.

GOEZ.—Recently I came upon a work, dated 1602, and entitled Travels of Benedict Goez from Lahore, in the Mogol's Empire, to China, in 1602,[1] which contains perhaps the earliest account, by a European author, of the production of jade in Kashgar. He says:—"The commodity best for carrying from Hirakan (*i.e.* Yarkand) to Katay (China) is a certain shining marble, which, for want of a fitter name, Europeans call jasper. The King of Katay buys it at a great price, and what he leaves the merchants sell to others at exceeding great rates. Of it they make vessels, ornaments for garments and girdles, with other toys, whereon they engrave leaves, flowers, and other figures. The Chinese call it *tushe.*[2] There are two kinds—one more precious, like thick flints, which are found in the river Kotan, not far from the city royal;[3] the other meaner sort is digged out of quarries and sawed into slabs about two ells in breadth. The hill where they are dug, called Kosanghi Kasho, or the stony mountain, is twenty stages from the same mountain. This marble is so hard that they must soften it with fire to get it out of the quarry. The king farms it every year to some merchant who carries provisions for the workmen for that space of time."

Goez mentions (p. 647) that besides this jasper (*i.e.* jade), "diamonds of the rock,"[4] and azure (*i. e.* lapis-lazuli) were carried as presents by ambassadors from the West to the Emperor of China.

As stated in my Economic Geology (p. 517), the mines of

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[1] New General Collection of Voyages and Travels. London: T. Astley. 1747. Vol. iv. p. 645.

[2] In the original, *Tusce*—a mistake, no doubt, for "*Yu she.*"

[3] By the Jesuits' map the river of Kotan runs about ninety miles east of Yarkand.

[4] I am not quite clear as to the precise significance of this phrase, "diamonds of the rock," unless, perhaps, it is equivalent to "diamonds of the old mine," an expression apparently used for stones having crystalline forms, called *naifes* in India, as contrasted with "diamonds of the new mine," which were rounded pebbles.

Kotan are mentioned by Chinese authors who wrote 2000 years ago; and the system of dredging the rivers of that region for jade is known to have been in practice for many centuries. Other mines are situated at Karakash, in the Kuenlun range. These have been visited and described by several Europeans of late years.

Recently a rather general acceptance has been given to the view advocated at great length by Fischer, that the discovery of jade implements in Swiss lake dwellings is testimony of a prehistoric immigration of Asiatic tribes into Europe, as there is said to be now no known source of the material in Europe. This view has been, I understand, lately contested by Dr. Meyer, of Dresden, but I have not yet seen his work on the subject.

In the year 1609, De Boot published his famous work on precious stones. This, however, being merely a compilation as regards the information given about India, there is nothing in it which is not contained in the already quoted authors. It may also be added here, that the edition of De Boot's work, published by De Laet in 1847, only adds to his account facts derived from Methold.

JAHANGIR.—In the *Tusuk-i-Jahangiri* (1616),[1] an account is given of diamond mines in the Chutia Nagpur, province of Bengal, which I have shown to be indentical with the Soumelpour, visited and described by Tavernier, as will be mentioned on a future page. There is no local tradition as to the precise site of these mines, which, therefore, remain to be rediscovered; but the search was certainly conducted in the bed of the Koel river.

METHOLD.—Our next authority is an English traveller named William Methold, whose account[2] of a visit to the diamond mines, made by himself and others, is entitled Of the south-eastern parts, viz., Golchond, and other adjacent Kingdoms within the Bay of Bengala. The visit appears to have been made between the years 1622 and 1626, the latter being the date of the publication.

The mines were situated 108 English miles from Masulipatam; they had only recently been discovered by the chance finding of a valuable stone by a goat-herd: when seen by Methold they gave

[1] Translated by Blochmann, Jour. As. Soc. Bengal: vol. xl. p. 113.

[2] Purchas's Pilgrims, vol. v. p. 1002. London: 1626.

occupation, according to native report, to 30,000 persons, a large proportion of whom were engaged in baling out the mines by hand—a tedious operation still practised in some parts of India. The mines were farmed out by the king for a sum of 300,000 pagodas, but he reserved to himself all stones of above 10 carats weight. In 1622 the mines were temporarily closed, owing to an ambassador from the Great Mogul having demanded a tribute of 3 lbs. weight of the finest diamonds. The locality was situated on the Kistna river, and was probably identical with the Gani or Coulour of Tavernier, the exact position of which has only recently been satisfactorily fixed as being identical with the modern Kollur.

Lord.—In the year 1630, a clergyman named Henry Lord, who was attached to the English establishment in Western India, published a curious pamphlet, entitled The Discovery of the Banian (*i.e.* Brahmin) religion. In it he gives an account of the Brahmins' ideas as to the first discovery of diamonds. It is attributed by them to the first progenitor of the Sudras or lowest caste of Hindus. Now the diamond miners throughout India, with rare exceptions, so far as I have been able to ascertain, still belong, and have always belonged, either to the Sudras or the aboriginal tribes, with whom they are much mixed up. This fact I hold to be of much importance in connexion with the explanation which I have offered of the origin of the diamond mining fable in connexion with the accounts of it given by Marco Polo and Nicolo Conte.

Tavernier (1665–1669).—In the accounts of his several journeys in India, Tavernier has given us a considerable amount of information, the value of which is, however, affected by the fact that these accounts contain a number of internal inconsistencies which it is impossible to reconcile with one another.

Diamonds.—Upon this subject the old jeweller naturally discourses at length: as, however, I have already quoted his facts in a former Paper,[1] I shall only here mention that the diamond mines at Raolconda, Gani or Colour, and Soumelpour have been identified by me[2] with the modern localities, Ramulkota, Kollur, and a spot on the Koel river in the district of Palamow in Bengal. Another

[1] Journ. R.G.S.I., present vol., p. 10, &c.

[2] Economic Geology of India.

locality which he mentions, namely, Gandicota, has also been identified.

If Tavernier's statements regarding the discovery and cutting of the Great Mogul diamond are to be relied upon, then that stone must have been distinct from the koh-i-nur. When writing of their probable identity, I overlooked the independent evidence which exists as to the koh-i-nur having been in the possession of the Mogul emperors long previous to the time when, according to Tavernier, they acquired the Great Mogul.

Gold.—In reference to this metal Tavernier says:—"Towards the Thibet, which is the ancient Caucasus, in the territories of a Raja beyond the Kingdom of Cashemir, there are three mountains close by one another, one of which produces excellent gold. . . ."

"There is gold also comes from the kingdom of Tipra (Tipperah on the borders of Assam); but it is coarse, almost as bad as that of China."

If gold washing or mining was carried on in any part of Peninsular India at the time of his visits, it is certainly remarkable that he should have been unaware of it, especially as he had heard of its being worked for in Thibet and Tipperah. Still I cannot but suppose that there were washings in some remote regions of which he knew nothing.

Silver and Tin.—"As for silver mines (he writes), there are none in all Asia, but only in Japan; but some years since at Delegora, Sangora, Bordelon, and Bata (localities in the Malayan countries), have been discovered plentiful mines of tin, to the great damage of the English, there being now enough in Asia of their own besides (*sic* in English translation).

The statement about silver is inconsistent with another made subsequently, that in Assam there were mines of both gold and silver.

Rubies, Sapphires, &c.—What Tavernier says on the subject of these stones shows that he was unaware of the existence of any source for them in Peninsular India. He says that they occur in only *two* places in all the east, and then forthwith mentions *three.* "The first is a mountain, twelve days' journey, or thereabouts, from Siren (*i.e.* Siriam), toward the north-east, the name whereof is Capelan. In this mine are found great quantities of rubies and espinels, or mothers of rubies, yellow topazes, blue and white

sapphires, jacinths, amethysts, and other stones of different colours. . . . . ."

"The natives of the country call all coloured stones rubies, and distinguish them only by the colour: sapphires they call blue rubies; amethists, violet rubies; topazes, yellow rubies; and so of other stones."

The ruby mines are described in the Economic Geology of India, p. 427. They are situated about seventy miles north-east of Mandalay, the capital of Ava.

"The other place where rubies are found is a river in the Island of Ceylon. . . . The people make it their business to search among the sands for rubies, sapphires, and topazes. All the stones that are found in this river are generally fairer and clearer than those of Pegu."

"Some rubies, but more Ballei's rubies, and an abundance of bastard rubies, sapphires, and topazes, are found in the mountains that run along from Pegu to the kingdom of Camboya."

Whether by Camboya Tavernier meant Cambodia, beyond Siam, is uncertain; but he can scarcely have meant Cambay. He says that it is an error to suppose that emeralds are found in the East. Those exported from the Philippines to Europe were first brought thither by Spaniards from Peru.

In the above-quoted paragraph on gold in the region beyond Cashemir, the other two mountains he mentions produced "granats" (*i.e.* garnets), and "azure" (*i.e.* lapis-lazuli), respectively. This reference is, doubtless, to well-known mines of the spinel or Balas ruby, and lapis-lazuli, which are situated in Badakshan.[1]

In 1673, a work was published on Asia by John Ogilby, which, as giving an epitome of the knowledge possessed in England of the mineral resources of India at that time, is not without interest. But some of the statements are not founded on fact. Thus, he says (p. 105): "The Ganges is supposed to abound with gold and pearls, and from its bottom are fetched all manner of precious stones, on some of which are represented the shapes of beasts, plants, and other things." And again: "The Kingdoms of Golconda and Decan afford the inhabitants excellent diamonds. India also produces topazes, berils, rubies (which the Arabians call

[1] Economic Geology of India, pp. 429, 529.

yakut), hyacinths, granats, smaragds, chrysolites, amethysts, agats, Bezoar stones, and borax. Some places yield gold and silver and all manner of other metals."

Many of these minerals, it is believed, do no not occur in India proper, and the term therefore is probably used in a very extended sense, and hence misconception has arisen no doubt. On page 157 he makes a remarkable statement, which might be used in support of the view contested in an early part of this Paper, namely, that India received *all* her gold from abroad. He says "Hindostan (by which, perhaps, only the realm of the Great Mogul is meant) possesses great quantities of gold and silver; but all is brought thither by strangers, never returning out again, for they melt down the European or foreign coins, and recoin them with the Mogul's stamp."

In a map, published by Wells in 1700, the positions of the diamond mines of Coulour and Raolconda are given with much greater accuracy than is the case in Rennell's map, published at the close of the eighteenth century. I was, however, confirmed in my conclusion as to the identification of the former by a manuscript map by Col. Colin MacKenzie, dated 1798, which is preserved in Calcutta.

In the maps of both Ogilby and Wells, Narsinga, a place often mentioned in the early accounts, is indicated as being situated to the east of Bisnaguar (*i.e.* Vijayanagar).

HAMILTON.—Captain Hamilton, who traded in the East Indies between the years 1688 and 1728, is our next authority.[1] He informs us that iron was made into anchors at Balasore, apparently by European methods: if so, this was the first manufacture of that kind in India of which there is any record. He quotes a curious story as to mercury having been brought to Achin in Sumatra from the Andaman Islands by a native, who, having been held for some time as a slave, was allowed to revisit his country on several occasions, and after each returned with some mercury which, he stated, was obtainable there (*i. e.* probably in the Little Andaman). This statement, together with a consideration of the geological structure, has led me to suggest the possibility of a future discovery of the metal in the islands of the Andaman group. In age and in characters

[1] New Account of the East Indies, vol. i., chap. xxix. Maderas or Chinapatam.

there appear to be several points of resemblance between some of the Andaman rocks and those which contain the valuable mercury mines of California.

"The diamond mines, being but a week's journey from Fort St. George, make them pretty plentiful there; but few great stones are now brought to market there, since that great diamond which Governor Pitt sent to England. How he purchased it, Mr. Glover, by whose means it was brought to the governor, could give the best account, for he declared to me that he lost 3000 pagodoes by introducing the seller to Mr. Pitt, having left so much money in Arcat as security, that if the stone was not fairly bought at Fort St. George, the owner should have free liberty to carry it where he pleased for a market; but neither the owner nor Mr. Glover were pleased with the governor's transactions in that affair."[1]

"Some customs and laws at the mines are: when a person goes thither on that affair he chooses a piece of ground, and acquaints one of the king's officers, who stay there for that service, that he wants so many *covets* of ground to dig in; but whether they agree for so much, or if the price be certain, I know not. However, when the money is paid the space of ground is inclosed, and some sentinels placed round it. The king challenges all stones that are found above a certain weight—I think it is about 60 grains; and if any stones be carried clandestinely away above the stipulated weight, the person guilty of the theft is punished with death. Some are fortunate, and get estates by digging, while others lose both their money and labour."

The remaining two authorities among those Europeans who personally visited the mines they describe were, Mustapha,[2] a Turk, who traversed the diamond-bearing region of Chutia Nagpur in 1758, and Motte,[3] who was deputed by Lord Clive in 1766 to purchase diamonds at Sambulpur, on the Mahanadi. The facts they record are chiefly of interest as proving the existence of the industry at those periods, and need not be further dwelt upon here.

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[1] A different version of the transaction by Mr. Pitt himself was published after his death.

[2] Oriental Repertory, vol. ii. p. 261. London: 1808.

[3] Asiatic Annual Register. London: 1799.

In recapitulation of the conclusions which I have been led to as the result of this analysis of the facts recorded by the above-quoted writers, the following may be enumerated:—

First. The great antiquity of the knowledge possessed by the natives of India with reference to certain metallurgical processes, is, I think, fairly established. The most notable of these is, undoubtedly, that by which *wootz* or cast steel was manufactured. Probably the method of refining gold which is mentioned in the Ain-i-Akbari is also very old; but we have no earlier record of it. I question the accuracy of a statement made by Strabo, or at least its applicability, even in his time, to the whole of India, where he says, "The Indians, unacquainted with mining and smelting, are ignorant of their own wealth."

Second. Many ancient, long-forgotten mines, the names of which, only, have survived in more or less archaic garbs, have, by the methods here adopted, been identified with modern sites. In most of these cases geological evidence has established these conclusions, and in some instances they have been further ratified by local traditions acquired as the result of personal inquiries.

Third. Several fables of world-wide notoriety have been shown to have had their origin in *facts* connected with customs which were formerly little understood, but, being still in practice, are now susceptible of close examination and explanation.

Speaking generally, I venture to believe that I have in this Paper placed within the reach of historians a number of facts that serve to elucidate several subjects hitherto manifestly puzzling to those unacquainted with the results which have been arrived at by the systematic examination of the Geology of India.

ADDENDA AND CORRIGENDA.

P. 235, bottom of page, Blocks of unwrought fluor-spar were found in the Marmorata, at Rome: see Westropp, *Precious Stones*, p. 126.

P. 237, line 5 from bottom, The *Adamas* river is identified by Colonel Yule with the Brahmini; the Tyndis, and Dosaron, which intervene between it and the Mahanda, being, with the last-named, different outlets of the Mahanadi where it traversed the delta.

P. 239, line 18 from bottom, *Suvarna Bhumi*, I have been informed by General Sir Arthur Phayre, was probably the Indian name of Thatun, a port forty miles north of Maulmain, whence, up to 1855, gold was exported which had been brought from South-east Thibet and Western Yunan.

P. 240, after line 14 from top, insert The Chinese annalist Han -yo, who was killed A.D. 445, says that the products of India are elephants, rhinoceroses, tortoise-shell, gold, silver, copper, iron, lead, and tin.—Max Müller, *What India can teach us*, p. 276.

P. 241, line 5 from bottom, *for* "Christian named" *read* "Christian church named after."

P. 248, lines 1 and 3 from bottom, *for* "Contai" *read* "Conti."

P. 256, line 18 from bottom, *for* "1847" *read* "1647."

P. 258, line 2 from bottom, Capelan, I am informed by General Sir Arthur Phayre, is the Europeanized form of Kyatpen, a village in the neighbourhood of the mountains.

XXVI.—NOTE ON THE AMYGDALOIDAL LIMESTONE OF DOWNHILL, CO. DERRY. BY PROFESSOR J. P. O'REILLY, M.R.I.A.

[Read, May 21, 1883.]

SOME months ago I received from Professor Hull a set of specimens forwarded to him by Mr. Egan, of the Geological Survey. He described them as filling cavities in sheets of basalt at Downhill, Co. Derry, and added, "It seems to be the curious mineral mentioned by Portlock (p. 215 of his Report) as occurring in that locality." Mr. Egan further mentions, that a similar mineral is to be found at Ballymoney, Co. Antrim, associated with calcedony, and near Limavady, Co. Derry, where, in common with a hard, flinty breccia (such as occurs between the chalk and the basalt in various places along the great basalt escarpment), it appears to have its origin in masses of chalk and flint caught up in the basalt.

Portlock thus describes the mineral:—"A curious mineral occurs in soft amygdaloid at Downhill. It is oolitic in structure, consisting of spheroids cemented together by pure white carbonate of lime or by green earth. In the latter case it has much the appearance of pudding-stone. The spheroids are yellow, whitish, or greenish, and appear to be a mixture of the hydrocarbonates of lime and magnesia. The small cavities are lined with drusy crystals of pure white carbonate of lime: where exposed, the cement, yielding first, assumes a mammillated appearance."[1]

He further adds, that the greenish aragonite of Ballintoy and the brownish aragonite of Downhill both contain a sensible amount of strontian.

The samples forwarded by Mr. Egan show the more usual forms of occurrence of the mineral and the rarer forms. There is also one showing "obscurely the manner in which the mineral is often associated with aragonite."

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[1] Geological Report on Londonderry, p. 215.

The greater number of the samples show an oolitic structure such as is mentioned by Portlock, only that in none of them is the cement of green earth, some of this mineral being, however, present on one or two of the specimens.

It may be taken for granted that the samples forwarded are of the same nature as those alluded to by Portlock. The question is, Are they hydrocarbonates of lime and magnesia, as he presumes—that is to say, hydrodolomite, as suggested by Mr. Egan?

A fair sample of one of the specimens was analysed by Mr. Templeton, one of the students of the Royal College of Science, and the following are the results:—

CaO, ...	54·69
MgO, ...	0·55
Al^1O^3 & Fe^2O^3, . . .	0·87
Insoluble matter, . . .	0·54
CO^2, ...	43·54
Moisture, ...	0·31
	100·50

A portion of this same sample gave a density of 2·722. Hydrodolomite, according to Dana, has a density of 2·495; therefore, neither by analysis nor by density can this mineral be described as hydro-dolomite: both would make it simply carbonate of lime relatively pure.

However, the examination of the hardness showed that the white oolites cut ordinary limespar; therefore they must have a hardness greater than 3. Aragonite crystals they do not cut, both minerals appearing to resist about equally. The hardness of the oolites may therefore be taken at 3·5. The density, being merely that of pure calcite, would seem to argue against its being aragonite; but Naumann gives for aragonite in the *aggregated form*, as lowest limit of density, 2·7. These oolites are, strictly speaking, aggregates, and the density of 2·722 is admissible for their being aragonites. On the other hand, this density excludes the assumption of their being dolomites, the limits of density for which are 2·8 to 2·95.

In order, however, to test this point, samples were submitted to the action of acetic acid, which in all cases rapidly decomposed

the oolitic parts, but only partially, and in certain parts, in no ways, attacked the matrix of the oolites.

This matrix has a distinct colour and crystalline structure, but so far I have been unable to separate it in sufficient quantity to get its density. However, it would seem from the foregoing considerations that this mineral is really constituted of oolitic aragonite in a matrix which presents to a greater or less extent the character of dolomite.

XXVII.—REMARKS ON THE UNUSUAL SUNRISES AND SUNSETS WHICH CHARACTERISED THE CLOSE OF THE YEAR 1883. By REV. SAMUEL HAUGHTON, S.F.T.C.D., M.D., F.R.S.

[Read, January 21, 1884.]

The older writers on Astronomy, such as Brinkley and Maddy, state that, on the average, twilight lasts until the sun is 18° below the horizon. From this it has been computed that the height of the twilight-producing atmosphere is

40	miles	on	hypothesis	of	one	reflexion,
12	„	„	„	„	two	„
5	„	„	„	„	three	„
3	„	„	„	„	four	„

Herschel and Newcomb make no statement whatever as to the duration of twilight; Chambers (in his compilation) says that the average depression of the sun is 18°, which is reduced to 16° or 17° in the tropics, but in England a depression ranging from 17° to 21° is required to put an end to the twilight phenomena.

Dr. Ball informs me that Professor Schmidt, of Athens, gives (for that place) 15° 51′; and also that Liais (Paris) fixes the first twilight arc to set at 10° 41′, and the second arc at 18° 18′.

In the following conclusions, drawn from the phenomenal twilights of the autumn of 1883, I calculate the zenith distance of the sun, at the close of the phenomena, by the well-known formula

$$\cos z = \alpha + \beta \cos h,$$

where

z = sun's zenith distance.
h = sun's hour angle.
$\alpha = \sin \lambda \sin \delta$.
$\beta = \cos \lambda \cos \delta$.
λ = latitude of place of observation.
δ = declination of sun.

Observation (1).—Mr. Bishop, observing at Honolulu, found the phenomenal sunsets to commence on the 5th September, 1883, and to last up to $7^h\ 25^m$ P. M.

Here $\lambda = 22°.$
$\delta = 6°\ 16'.$

This gives the sun's place, at the close of the phenomena, 18° 20′ below the horizon.

This indicates twilight phenomena intensified by some unusual cause, but does not denote an extension of twilight reflexion into regions of the air higher than the time-honoured traditional 40 miles.

The epoch of the main eruption of Krakatoa has been fixed by General Strachey at August, $27^d\ 9^h\ 32^m$, A.M.

If the explosion of Krakatoa, on the 27th August, was the cause of the brilliant sunset at Honolulu, on the 5th September, the result is nothing short of miraculous!

The Editor of *Nature* writes, on the 20th December, with an enthusiastic glow worthy of the twilights:—"The extraordinary fact now comes out, that before even the lower currents had time to carry the volcanic products to a region so near the eruption as India, an upper current had taken them in a straight line *viâ* the Seychelles, Cape Coast Castle, Trinidad, and Panama, to Honolulu; in fact very nearly back again to the Straits of Sunda!" [The note of admiration is not mine.]

It is worth our while to calculate the rate at which this wonderful journey of volcanic dust was performed. The actual distance is 255° of a great circle, and the time of journey 9 days, from which I calculate the speed of the train to have been 82 miles per hour! This is absolutely incredible, and becomes still more so when we know that the phenomena observed at Honolulu on the 5th September were unusual twilight phenomena, but had no connexion whatever with reflexion from the upper regions of the air. In point of fact, my calculation of the sun's position disproves the presence of dust, or any reflecting substances in the upper air.

Observation (2).—Dr. Ball (Dunsink).—"Sunday evening, 30th December, was exceptionally fine, and the sunset was so well seen

that the moon (though only 27 hours old) was well seen by Cathcart and myself from the roof of the Observatory.

"We estimated that the twilight lasted certainly for two hours after sunset, and that for ten minutes longer there was still enough light in the western sky to distinguish it from other parts of the horizon.

"At two hours after sunset the sun was 15° 56′ below the horizon, and at 2^h 10^m it was 16° 51′ below the horizon."

Observation (3).—On the 25th December Mr. William Graves, observing at Kingstown, found it was "black night" at 5·30 P.M. This gives 14° 15′ below the horizon for the sun's position.

Observation (4).—Mr. Frederick Haughton, writing from Carlow, says, of the eveuing of 30th December:—"I have of course seen a good deal of the after-glow: some evenings the appearance is like the glare of lime-light at a theatre; the effect on grass or gardens very strange; with back to west every blade of grass is like fire, a bit of straw like a red-hot needle; but facing the light it is all lurid light and shade. Last night sun set by almanac at 3·47; here the sun disappears 20 to 25 minutes before, owing to hills; at 4.30 the glow was splendid; at 5·10 I could see the second-hand of watch. 1 hour 23 minutes after sunset, or nearly 1¾ hour after sun had vanished from us, a planet[1] from 4·30 to 5·30 was in the glow; and from 5 to 5·30 was bright emerald green!"

Supposing the termination of the phenomena to be at 5·40 P.M., this would correspond to a position of the sun 15° 15′ below the horizon.

[1] Venus.

XXVIII—NOTES ON THE CLASSIFICATION OF THE BOULDER-CLAYS AND THEIR ASSOCIATED GRAVELS. By G. H. KINAHAN, M. R. I. A.

[Read, January 21, 1884.]

The phenomena to be observed in connexion with the boulder-clays and their associated gravels, &c., especially in Ireland, are far from having been satisfactorily explained; it may therefore be allowable to make some remarks on them.

It would appear as though the present confusion is in a great measure due to observers rushing to conclusions without sufficient and careful examination or thought, and also forgetting to compare the deposits that they would explain with those that are being laid down at the present time.

There are three classes of more or less similar drifts, which are commonly called boulder-clay:—

1st. The Till, or the Lower Boulder-clay.
2nd. Moraine Drift, or the Upper Boulder-clay.
3rd. Glacialoid Drift.

Nos. 1 and 2 are true glacial drifts; while No. 3 was originally glacial drift, but has subsequently been re-arranged, either by water or atmospheric agencies. Associated with all, but especially the last, there are gravels, sands, with brick and "book" clays, or, under certain circumstances, marls. These occur sometimes above, sometimes below, but more often in different intermediate positions, while in general the relative positions of these different drifts are supposed to indicate their relative ages. This, however, appears to me to be "not proven," as the facts observed by Clarence King on the Western Pacific slopes, and by Hayes and others in Arctic and Alpine regions, combined with what can be studied as taking place at the present day in Great Britain and Ireland, would suggest otherwise.

Prior, however, to going further into these subjects, we may give a *résumé* of the principal sections in Ireland that are said to afford conclusive evidence of there having been upper and lower glacial drifts, with "middle gravels" of an intermediate age between them.

There are, indeed, in the neighbourhood of different groups of hills two distinct varieties of boulder-clay, viz. *till* below, and *moraine drift* above; but although in general there is a line of boundary between, yet they are rarely separated by aqueous deposits; while if they are so, the latter usually consist of from a few inches to a few feet in thickness of fine sand or finely laminated clay (*book clay*); and in such places there is nearly always a "lining" or rude stratification in the overlying moraine drift, as if it had been finally arranged in water—or as if it had slipped down from a higher level in the state of mud, or of mud and ice-slush mixed together. In many places the latter is suggested, as on the low, flattish ground this lining may be very conspicuous; while as we ascend to the higher sloping ground all traces of this stratification gradually disappear.[1] In no place, however, have I seen regular continuous sands and gravels between these upper and lower glacial drifts; although in places, more especially along some of the sea cliffs, there are miles of sections exposed.

The section which appears to be most relied on as a proof of the existence of these "middle gravels" in Ireland is that at the Kilkenny marble quarry. Here, however, the upper member is not a *true* glacial drift, but a very typical estuarine accumulation—one common in the deep-seated Irish river-valleys, having in it many striated fragments, but all more or less water-worn, while it is similar to drift now accumulating in different long, narrow estuaries. In some of these recent estuarine accumulations I have found over 50 per cent. of these striated fragments.

In various places along the coast from Killiney to Bray, both in the railway cuttings and the cliff sections, it is quite evident that the gravels, brick-clays, &c., were deposited at the base of a boulder-clay cliff, which at times slipped down and covered them,

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[1] As has been pointed out elsewhere, on the N.W., or Carlow, slopes of Mount Leinster, there is a lined glacialoid moraine drift that now extends out on to a recent peat bog ("Geology of Ireland," p, 236).

thereby causing glacialoid drift to dovetail and merge into gravels, sands, and clays.

More or less similar phenomena can be seen in the coast cliffs of Wicklow, Wexford, Waterford, Louth, Down, Antrim, &c., and inland in numerous places. Inland, especially in the Co. Tyrone, the gravel is often found surrounding glacial drift-hills, but in such cases never extending through them, as is proved by the railway cuttings. A very instructive case occurs at Redhill, to the west of Boyle, Co. Roscommon, and is described in the Geological Survey Memoirs by Mr. Cruise.

In some places, as in the vicinity of Pomeroy, Co. Tyrone, an angular, shingly drift has been called "upper boulder-clay," although there is not a particle of evidence to suggest a glacial origin; while elsewhere high level gravels, as on Slieve Gallion Carn, Co. Londonderry, are said to be of the same age as the gravels of the low neighbouring plains, and as they are under glacial or glacialoid drifts, are said to prove that the latter are those so-called "middle gravels"; although it must be evident to anyone who examines them thoroughly, and carefully considers the subject, that the higher gravels must be quite distinct, and are probably older than the lower ones.

The result of many years' minute examination and consideration of the drift accumulations in various places in the United Kingdom, combined with a study of the published descriptions of drift sections by numerous observers there and elsewhere, would lead me to suggest—

First—That some of the gravels and other stratified drifts under glacial drifts may be younger than the overlying deposits.

Second—That many of the sands and gravels in the till and moraine drifts are probably younger than the materials now lying over them; and

Third—That gravels, sands, and other stratified drifts contemporaneous with the allied glacialoid drift, must in general be younger than the associated glacial drifts; the exceptions being few and rare.

As to the first: in certain places the till or moraine drifts may have accumulated over deposits of gravel or such like; but in other

places it seems highly probable that the gravels now found under them were due to the water formed in the ice before and during its final melting, producing streams under the glacial drift, thereby washing portions of it into gravels and sands. This is specially suggested by finding boulders in places in these accumulations, while the stratification is distortrd as if by currents curling round the boulders, or by the roof falling in; also, many of those who have studied "live ice" mention the streams that flow from beneath the glaciers and ice-sheets.

As to the second: Clarence King and others who have studied the dying-out of ice-sheets have found that the ice melts from above and below, leaving to the last patches and cakes on different horizons. The waters due to such cakes, when they finally melt away, must wash portions of the glacial drift into sands and gravels formed and arranged subsequently to the overlying drift.[1]

Similarly in the till and moraine drifts we find on different horizons, cakes and patches of gravel and sand, often very irregularly stratified, as if there was a curling current, or that the roof and sides of the cavities fell in, as the cakes of ice gradually melted away. In various Papers on the English and Scotch drift such cakes and patches of sand and gravel on different horizons are appealed to as proofs of the existence of "middle gravels" of intermediate age; but, if my theory is correct, they are younger than the overlying deposits. Also, if large debacles of glacial mud slide down to form the upper drift, the water from the snow-slush, or even from the mud alone, should form sands, "book clays," and the like, between this soft matter and the harder floor beneath.[2]

As to the third: gravels and other stratified drifts, when associated with glacialoid drifts, must be younger than the original glacial drift with which they are connected; as the glacialoid drifts were formed from the *debris* of the last, while they are interstrati-

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[1] Some of the cakes may be isolated and surrounded by the clay, thus forming "lough holes" like those cut when making the railway under the Phœnix Park, Dublin. These lough holes seem to have been filled for the most part with water, there being only a little sand.

[2] If the floor is a rock surface we find in uneven places small patches of these stratified drifts, which apparently were formed subsequently to that over them, as they fit the roof of the cavity similar to matter found filling a rock cave.

fied with the first. If the original drift cliff was perpendicular, or nearly so, the gravels would accumulate against it, whilst subsequently detritus, composed by weathering from the upper portion of the cliff, would cover them up; but if there were periodical falls or slips of the cliff, the gravels and glacialoid drifts must in some places be more or less interstratified, whilst elsewhere they would blend or graduate into one another, as can be seen in numerous places along the already-mentioned Irish coast cliffs.

XXIX.—NOTE ON THE COAL DEPOSITS OF THE NORTH-WEST TERRITORIES OF CANADA. By GERRARD A. KINAHAN.

[Read, February 18, 1884.]

As some doubts are still often expressed in this country of there being sufficient fuel in the North-West to supply even the local requirements of Manitoba, Assiniboia, and Alberta, a short note on the lignite deposits of this region may be of some interest to the Members of this Society.

The formations in which these beds occur are considered by the Officers of the Geological Survey of Canada to be of later Cretaceous or early Eocene age, and in some cases there is evidence of the lignites occurring on two distinct geological horizons, very possibly representing a period intervening between the Mesozoic and Cainozoic of Europe. The lignite-bearing series probably underlies a large portion of the prairie lands of the North-West, being concealed by a thick covering of drift gravel and alluvium; its outcropping at the surface is generally the result of gentle undulations of the strata and subsequent denudation.

In the eastern portion of the area the fuel is more truly lignitic; but westward, especially in the folded and compressed strata composing the foot-hills of the Rocky Mountains, it more nearly approaches in lithological characters true coal. West of the Foot-Hills this formation is cut off by an immense fault with a large downthrow to the east, beyond which break Palæozoic limestones and quartzites form the precipitous and craggy range of the Rocky Mountains. That the lignite-bearing series formerly had a wider distribution and covered much of these Palæozoic rocks is evident from the fact that, far in in the mountains, a small patch of them occurs, resting on the older rocks, which have here been let down by a series of faults, thus preserving the overlying series from being denuded away. Here the lignite has been converted into a semi-anthracitic coal of very excellent quality, free from pyrites and slate, and quite undeserving of the name of lignite in any sense but that of being of post-carboniferous age. It appears on the Devil's Creek, or north fork of the Bow River, at Cascade Park,

twenty-five miles from Padmore, and about eighty miles west of Calgary, close to the line of the Canadian Pacific Railway. But although this valuable deposit has been known for many years to some of the early prospectors of this section of the mountains, it was not till last summer that the location was secured, and in the Fall active operations for extracting the fuel commenced.

Along the belt of the Foot Hills, where the strata are more folded and indurated than on the plains to the east, the coal seams crop out more highly inclined, and the beds are probably often repeated. About twenty-eight miles from Calgary, and ten miles east of Morley, an important coal outcrop occurs in these beds; it is that of Coal Creek, in the Wildcat Hills, on the Cochran Ranche, where the seam appears to be about five feet thick, dipping east, at an angle of about 30°, under a series of cream-coloured sandstones. Most of the other outcrops in this belt are too far removed from the line of railroad or other convenient means of transport to be of much economic value at present, but eventually many will probably prove important. Dr. G. M. Dawson has recorded several outcrops in this district, as that on the Big Cottonwood River, north fork of Highwood River, and the north fork of the Old Man's River, near the Crow's Nest Pass, and on the middle fork in the vicinity of the Kootenai Pass; also a thick seam, about ten feet wide, on Mill Creek; these two last locations are about forty miles west of Fort M'Leod. On a specimen from an outcrop on the Indian Supply Farm, a little further south-east, Mr. Hoffmann publishes a report and an analysis[1] which may be quoted:—

"Colour, pure black; structure, lamellar; lustre, shining resinous, with occasional dull patches; powder, black, the same communicating a deep brownish-red colour to a boiling solution of caustic potash.

"ANALYSIS BY SLOW AND FAST COKING.

	Slow Coking.	Fast Coking.
Hygroscopic water,	6·26	6·26
Volatile combustible matter,	29·31	31·96
Fixed carbon,	55·70	53·05
Ash,	8·73	8·73
	100·00	100·00

[1] Chemical Contributions to the Geology of Canada (1880), by Christian Hoffmann, F. Inst. Chem. (page 12).

"Both slow and fast coking gave a *pulverulent* coke. The ash had a pale reddish-brown colour, and agglutinated slightly at a bright red heat."

These localities all lie to the south of the Canadian Pacific Railway, towards the United States boundary; but to the north many other outcroppings also occur in the Edmonton district, one seam, twenty feet thick, appearing on the Saskatchewan, above Edmonton, and another, eight feet thick, on the Pembina River.

In the vicinity of the railway, on the Bow River, there are two important outcrops, near the Blackfoot Crossing, and on Crowfoot Creek; these locations are about sixty miles east of Calgary and one hundred and ten west of Medicine Hat, where the seams vary from three to nine feet thick, and dip gently towards the west; other outcrops occur on the Red Deer River, which lies to the north. The following analyses have been published by Mr. Hoffmann:—

	Blackfoot Crossing.		Crowfoot Creek.	
	Slow Coking.	Fast Coking.	Slow Coking.	Fast Coking.
Hygroscopic water,	10·72	10·72	11·25	11·25
Volatile combustible matter,	29·26	32·63	31·98	35·59
Fixed carbon,	46·09	42·72	50·85	47·24
Ash,	13·93	13·93	5·92	5·92
	100·00	100·00	100·00	100·00
Ratio of volatile combustible matter to fixed carbon,	1 : 1·57	1 : 1·31	1 : 1·59	1 : 1·33

These samples gave a pulverulent coke, and agglutinated slightly at a bright-red heat. The coal is of a black colour with a brownish tinge, and contains thin films of selenite.[1]

[1] From these analyses, by fast and slow coking, of the proximate composition of the coal we may roughly appreciate its value as a fuel and gas-producing material, though the fixed carbon and volatile matter vary *inter se*, according to the method of coking: of course the ash and hygroscopic water are constant under both conditions. "Lignites" always contain a large percentage of the latter, so that its accurate estimation is of the utmost importance. In these samples the hygroscopic water appears to be exceptionally low: for lignites generally the average percentage varies from 15 to 25 per cent., and in exceptional cases it runs as high as 50 per cent. However, the action of caustic potash in the present instance indicates the lignitic character of the fuel. Another important point to be determined in estimating the commercial value of lignite is the question of weathering. Most of the lignites of the north-west appear to bear the weather and transport well, the arid climate and the comparative freedom of the coal from unstable pyrites being specially favourable for their nondisintegration.

There is also a large coal district on the South Saskatchewan, about Medicine Hat; some of the seams can be seen cropping out almost horizontally, on the banks of the river, a few miles above the latter place. But probably the most important coal deposit in the North-West is that of the "Coal Banks," on the Belly River (one of the main tributaries of the South Saskatchewan), twenty-five miles east of Fort M'Leod and about one hundred and twenty miles south of Medicine Hat. Here the seam is about nine feet thick, and dips at a very low angle to the west. This locality is now being actively worked by Sir A. T. Gault. The coal is taken in barges and steamers to Medicine Hat; hence it is distributed east and west along the line of railway: it is a fine semi-bituminous coal, containing a little pyrites, and not unlike some Welsh steam coals: it appears to be admirably adapted for steam-engines and domestic purposes, and is being used on the locomotives of this section of the railway, and also on the steamers plying between Medicine Hat and the mines; it produces a very hot fire, and forms very little clinker or cinder.

Besides the localities above mentioned many others are known, especially in the district to the north; to the east, on the Souris plain, the beds are much more lignitic in character than to the west.

Although it is only quite lately that these coals have been extensively used throughout the country, they have been employed to a limited extent, for some time past by the North-West Mounted Police and by the pioneers of the district; yet it seems highly probable that, on the development of the mines, and extension of the railway, these coals will not only be almost exclusively used throughout the territory, but that there will be a large export trade to other districts.

XXX.—THE PHOSPHORITE NODULES OF PODOLIA.—NOTES BY J. P. O'REILLY, Professor of Mining and Mineralogy, Royal College of Science, Ireland.

[Read, March 17, 1884.]

At a recent Meeting of the Natural Science Section of the Royal Dublin Society, Professor Valentine Ball submitted for examination, and made some remarks on, specimens of the globular or spherical concretions of Phosphorite imported into this country from Podolia, in southern Russia. Their singular form, their remarkable size, and radiated fibrous structure, excited curiosity and discussion as to their origin. Wishing to arrive at some solution of the problem thus apparently presented, and assuming that a mineral of this remarkable character and of such industrial importance must have undergone chemical investigation and been scientifically noticed, I had recourse to the authorities at hand in the College Library, and was enabled to get from them a sufficiently detailed account of the mineral itself, of the nature of its deposits, and its probable origin. At the same time I received, through the kindness of Mr. N. Stadnicki, son of Count Stadnicki, on whose estates in Podolia large deposits of this mineral exist, a fine collection of the balls in different states, which enable me, I consider, to push the question a stage further than that arrived at in the memoirs which I am about to cite.

The first notice which I met with was the excellent article on Phosphorites, forming one of the parts of the *Encyclopédie de Chimie de Fremy* (tom. v., 1st section, 2nde partie, p. 89), wherein the locality of the deposit is noticed and a summary given of a memoir on these phosphorites, by Fr. Schwackhöfer, published in the *Jahrbuch der Kais. Kön. Geolog. Reichsanstalt*, 1871, xxi. Band, p. 211. This memoir is very complete, and accompanied by plates. He opens by explaning that the Silurian formation, which extends over a great part of Northern Bukovina and Russian Podolia, is mainly represented by compact and highly fossilised limestones and clay slates. Directly on these rest regularly stratified beds of

chalk—sometimes those containing flints, known in the country by the name opoka; sometimes the green sands.

The silurian slates present two very distinct forms—the one large-grained, and compact, with rough surfaces, greenish-brown colour, giving rise, by splitting, to thick flags; the other, slaty in its texture, composed of thin, even, greasy, lustrous, and friable plates of a greenish-black, or, more rarely, greenish, colour. This latter form is that occurring in Russian Podolia, and is characterised by its greater tendency to weathering, giving rise to more rounded outlines of country. The first-mentioned clayslates produce in the valley of the Dniester and its confluents very abrupt banks, sometimes almost perpendicular. The thickness of these clayslates is several hundred feet. It is in the greenish-black and thin-plated clayslates that the globular phosphorite is exclusively found, these beds being, according to Blœde and Barbot, referable to the Silurian formation.

The phosphorite balls are interstratified with these slates, often in great quantities. Owing to the tendency to weathering of the slates, the balls give rise to secondary deposits, such as the detritus heaps of the chalk beds, and are found thus along the banks of the Dniester, even far into the river bed.

The localities marked by the more frequent occurrence of the phosphorite balls are situated on the left bank of the Dniester, in the zone of country lying between S[ta] Uszica and Mogilew. Very fine surface deposits are met with at Zurczewka, Kaljus, and Ljadowa.

The mineralogical characteristic of the Podolian phosphorite is, that it occurs, almost without exception, in a spherical or globular form, showing an inner concentric radiated structure.

The surface is uneven, often foliated, feels greasy, and presents a dark-green colour, somewhat like that of fresh cast iron. The balls, disengaged from the matrix by erosion, and having undergone abrasion, present a bright-grey and even surface.

The diameters vary from 2 cm. to 16–18 cm., generally 5–6 cm. The density is from 2·8 to 3. The hardness about that of fluorspar.

The radiated structure is not in all cases the same: in some this structure is more marked towards the periphery, becoming indistinct towards the centre, where it appears compact; the core

at the centre being in this case of crystalline foliated calcspar of a bright-grey or greyish-brown colour, showing generally a star form. In others the radiated structure is equally distinct all through, and at the centre is found a star-formed hollow space, filled with a brown earthy mass. The former generally presents a more greyish colour; the latter a very distinctly brown colour. Between the radiating fibres or bands occur various enclosed minerals, such as calcite and plates of pyrites, little grains of quartzite, small quantities of a yellow powder, composed of manganese carbonate, a dark-brown pulverulent mass, which is a mixture of iron oxide and carbonate of iron, and finally an aluminous silicate in the form of a white earthy mass. Occasionally particles of galena occur sprinkled through the mass.

Several Tables of Analysis are given, one of which gives in constituents the composition of the inner and outer zones of the specimen analysed; another that of the core or kernel; and another that of the matrix of the phosphorite, which shows whence the phosphoric acid proceeded.

I.—Constituents of the Outer and Inner Zone of a completely-altered Phosphorite Ball of 15 cm. Diameter.

	Outer Zone.	Inner Zone.
Tribasic lime phosphate,	79·70	87·61
Phosphoric acid,	0·03	0·29
Calcium fluoride,	6·16	7·29
Calcium carbonate,	0·68	0·61
Sesquioxide of iron,	2·65	1·06
Manganese hyperoxide,	—	0·57
Lime silicate,	0·26	—
Soda silicate,	0·46	—
Alumina silicate,	3·99	1·01
Silica,	4·54	0·32
Organic matter,	1·39	0·79
Water,	0·72	0·53
Total,	100·58	100·08

II.—Constituents of the Core, the Middle and Outer Zone of an incompletely-altered Phosphorite Ball of 15 cm. Diameter.

	Outer Zone.	Middle Zone.	Core.
Tribasic lime phosphate,	82·66	83·33	53·70
Phosphoric acid,	0·03	0·43	0·96
Calcium fluoride,	6·42	6·85	4·58
Lime carbonate,	1·95	5·27	37·02
Pyrites,	1·08	—	—
Ferric oxide,	1·24	1·80	1·35
Potash silicate,	0·51	0·33	0·24
Soda silicate,	0·67	0·44	0·32
Alumina silicate,	0·55	—	—
Silica,	2·63	0·87	0·25
Organic matter,	1·60	0·89	0·78
Water,	0·57	0·38	0·31
Total,	99·91	100·59	99·51

III.—Matrix of the Phosphorites, Silurian Slate Rock of Zurczewka.

	Soluble and Insoluble Parts in Hydrochloric Acid in 100 parts.		Sum.
	Soluble.	Insoluble.	
Ferric oxide,	4·78	1·58	6·35
Ferrous oxide,	2·70	Traces.	2·70
Manganese oxide,	—	—	Traces.
Alumina,	8·86	12·68	21·54
Lime,	1·47	Traces.	1·47
Magnesia,	1·11	0·41	1·52
Potash,	1·23	1·83	3·06
Soda,	0·21	2·03	2·24
Silica,	Traces.	55·36	55·36
Carbonic acid,	0·42	—	0·42
Phosphoric acid,	0·33	—	0·33
Sulphuric acid, chlorine, fluorine,	—	—	Traces.
Organic matter,	—	4·06	4·06
Water,	1·35	—	1·35
Total,	22·46	77·99	100·40

Schwackhöfer details fully and discusses the method of analysis followed, and the appropriation of the elements found, to the constituents mentioned in the Tables, and shows, from the comparison of Tables I. and II., that the lime phosphate of the Podolian phosphorites stands in relation to the calcium fluoride in exactly the same ratio as occurs in apatite, and that therefore we may admit that the mode of formation is the same as that of apatite. He demonstrates this by a Table.

He further shows that between the apatite constituent and the lime carbonate of the inner bands of the phosphorite there is a constant ratio, the sum of the two constituents being a constant, as is shown in the accompanying Table:—

	I.	II.	
	Inner Part.	Middle Part.	Core.
Lime phosphate, ...	94·90	90·18	58·28
Lime carbonate, . , ...	0·68	5·27	37·02
Total, ...	95·58	95·45	95·30

As regards the surface coating this relation does not hold, on account of the presence of incorporated foreign bodies.

The author then proceeds:—"From the foregoing data, as to the nature of the deposit, mode of occurrence, and chemical consitution of the phosphorite, sufficient ground is afforded for answering the question, *How have these phosphorites originated?*"

The opinion received up to then, and put forward by the author, had been, that these concretions were originally formed of carbonate of lime, which was altered into phosphorite by the phosphoric and fluoric combinations washed out of the slate rocks. This opinion he now, to a certain extent, modifies.

He considers that the material for the formation of the calcite concretions (specimens of which he found composed of finely crystalline calcite, with some phosphoric and silicic acid, the calcite being always at the core and concentrically formed round the centre) was furnished undoubtedly by the chalk marl (opoka),

which ordinarily overlies the phosphorite deposits in thick beds, or the former existence of which is at least proved by the remaining flint nodules.

The washing out of the lime by rain charged with CO^2, and the passage of the lime carbonate into the underlying beds, is, he says, easily explainable, as also the separating out of this bicarbonate as simple lime carbonate, and the concentric layering of the simultaneously-formed lime particles around the previously formed core, with intervention of a lime silicate as a cement. That the process was gradual is shown by the shell-like structure of the concretions, as also by the apparent crushing of the slates in contact with the balls. He further shows that the assumption that elements requisite for the transformation of the lime carbonate into apatite proceeded from the slate is not a mere guess, but is sustained by the analyses of the mother rock, wherein phosphoric acid in determinable quantity is shown to exist, as also traces of fluorine. He attributes the clefts in the "completely infiltrated balls" (in which there is no calcite kernel), as also the radiated structure of the phosphorite, to a *contraction* of the matter consequent on the metamorphosis of the calcite balls of crystalline granular texture. This contraction had for consequence the change of texture from finely granular into radiated fibrous; and he enters into an examination of the volume ratio between the calcite and subsequent apatite. This explanation supposes that the phosphoric acid penetrated the calcite balls from outwards inwards in solution (as acid lime phosphate); that thus the tenor in calcium, which for apatite is 39·68 per cent., and for calcite 40 per cent., that is, nearly the same, remained unchanged during the metamorphosis; and he cites experiments to prove this.

In the main, therefore, Mr. Schwackhöfer considers that the origin of the nodular phosphorites was the metamorphism of nodules of calcite into apatite. But it remains to be shown that such calcite nodules are usually to be found in Silurian slate-rocks, or that calcite usually occurs in that form: furthermore, that a change from a compact texture to a radiated fibrous structure, such as is shown by the phosphorite, is admissible in this case, or explainable by change of volume and contraction.

The examination of the samples received from Podolia, through Mr. N. Stadnicki, seems to me to point to another and less imme-

diate origin. Amongst those specimens are pieces of balls entirely composed of iron pyrites: one of these pieces is distinctly marcasite, or liver pyrites, the characteristics of which are so well known. Moreover, while pyrites occur in nearly every rock, marcasite is more particularly associated with marls and clay beds, and in this respect the observation of Mr. C. Mène (C. R. lxiv. 867), cited by Dana in his 5th edition, p. 800—that the pyrites of unaltered sedimentary beds is mostly marcasite, while that of metamorphic rocks is ordinary pyrites—is interesting and to the point. If now we consider a bed of clayslate, in which originally marcasite nodules were developed, these, by subsequent changes of sea level, superposition of chalk-marl beds, and slow infiltration of solutions containing carbonic acid and other constituents taken from the chalk marls into the underlying slate rock, would undergo transformations which might result at a certain state in calcite; and then the subsequent changes would be explainable in the way pointed out by Mr. Schwackhöfer. The examination of a nodule of marcasite or liver pyrites undergoing decomposition points to this solution, since it shows not merely a radiated fibrous structure exactly as that of the phosphorite balls, but also a change of volume consequent on the formation of sulphate of iron. This change is an increase; the mineral is therefore rent, and presents clefts exactly as those occurring at the centre of certain of the nodules of phosphorite. The hollowness of these clefts, or the absence of contained matter, is easily accounted for, since these clefts would be filled by the iron salt, and this would be the last removed, if the action proceeded from the periphery towards the centre, and would either be replaced by another mineral, if the solution could give anything, or would simply be removed by the passage of water. There would not, therefore, have been contraction, but rather the contrary increase of volume, which precisely rendered the mineral more apt to give passage to subsequent infiltration and metamorphism. As to the series of changes having led up to apatite, it is presumable that it was more complex than that assumed by Schwackhöfer, who starts with calcite nodules.

Starting from marcasite nodules, the clefts would tend to show that change to sulphate of iron took place first, and that it was complete. It must be borne in mind that these nodules, being entirely enveloped by clay more or less plastic, were protected

from disintegration, and that subsequently the iron was replaced by lime, giving rise to gypsum, which could in turn give rise, by metamorphism, to calcite, and this to apatite.

What must be borne in mind in a case like this is, that the series of geological changes which took place in the country of the deposits must have been closely connected with these pseudomorphisms ; and that the fact of the beds having undergone great variations of level, with change of pressure, change of temperature, change of permeating solutions, both as regards constitution, concentration, temperature, and pressure, the final state and products which we examine must be the resultant of all these actions.

That the pyrites now remaining in the beds are still undergoing decomposition would seem to be shown by the existence of chalybeate springs in the district. How far this would point to a stage of change, wherein the sulphur was removed as sulphuretted hydrogen, is a question to be discussed. Organic matter is shown to exist in the balls, and such organic matter would be highly conducive to this process of removal. Furthermore, relatively small quantities would produce this result if caused to pass continuously through the nodules, so that what would finally remain after complete removal of the sulphur would be seemingly insignificant.

There is a last remark to be made, from a practical point of view, relative to this change of marcasite into apatite : it is, that indications of marcasite would *pro tanto* be possible indications of phosphorite deposits, and would therefore serve as a guide for their research.

XXXI.—NOTES ON THE MICROSCOPICAL CHARACTER OF THE VOLCANIC ASH FROM KRAKATOA. By J. JOLY, B. E., Assistant to the Professor of Engineering, Trinity College, Dublin. Plates IX. and X.

[Read, March 17, 1884.]

On the 26th of August, 1883, the Norwegian barque *Borjild* (Captain Amundsen), on her way from Cherribon to Anjers, cast anchor off the east coast of the Great Kombuis Island, some seventy-five miles to the north-east of Krakatoa. Here she remained during the period of the eruption; volcanic ash falling on her decks from 6 A.M. to 6 P.M on the 27th. On that day, at 2 P.M., the darkness, due to absorption by the great layer of dust above them, was described as being so intense that mutual recognition by vision was impossible.

In the month of February, during the stay of the *Borjild* at Dublin, a portion of this ash was, through the kindness of Mr. Hogg, of Trinity College, obtained by the author. The examination of this ash forms the subject of the following notes.

Mere inspection with a lens shows the ash to consist principally of vesicular fragments of pumice interspersed with vitreous and crystalline particles. Before dealing with these it is interesting to note the presence, as of accidental origin, of—

Sodium Chloride.—The presence of this substance may readily be demonstrated by taste; or by immersing in distilled water and testing. Mr. Moss, who first called attention to it, estimated it to be present to the extent of 0·8 per cent.

Organic Marine Remains.—Those noticed were foraminifera, of which some quite perfect shells were found, and also fragments of starfish (identified by Professor Sollas). Similar remains were removed from the external cells of a specimen of the "floating pumice," picked up by the *Borjild* in the Straits of Sunda.

Perfect identity, mineralogically, seems to exist between this floating pumice and the ash. Larger crystals may, however, be obtained from the former than from the latter. Feldspar crystals

3 mms. long were found protruding from the abraded surface of the block pumice. In the dust they rarely exceed 1 mm. in length. The formation of the dust by mere pulverization of the pumice seems a most likely supposition.

With regard to the *modus operandi* of preparing this dust for the microscope, it may be useful to note that while it was found that mere shaking up with water, and pouring off before complete settlement, served to remove the lighter fragments of pumice, complete separation was only readily effected by the following method :—

Into a glass tube 1 m. long and about 4 cms. in diameter, closed at one end and filled with water to the brim, the partially cleansed dust is introduced and allowed to settle. A slip of glass is now pressed on the open end, and the whole rapidly inverted into a shallow dish containing water. The denser particles descending most rapidly through the column of water in the tube reach the dish first. When the more slowly moving particles are observed to have nearly attained the dish, a movement of the tube to one side effects the desired separation.

One and all the constituents of this ash present under the microscope a spectacle of the most extreme interest and beauty. The almost unlimited minuteness of the vesicular structure of the pumice, the endless variety in form and colour of the amorphous fragments, the exquisite perfection of form exhibited by the minute crystals of magnetite, of pyrites, of pyroxene and of feldspar ; the nebulæ of enclosures in these last, and their delicate overspreading lace-work of still adhering vesicular glass. Here are seen small crystals enclosing many others, and these again, still others ; while often with the symmetry of the crystal the vitreous inclusions, amber-yellow, range in concentric zones in the translucent depths.

But if this be a wonderful spectacle viewed by ordinary transmitted light, the beauty and wonder of it are a thousandfold increased when, rotated in polarized light, each feldspar crystal reveals its molecular symmetry in flashes of changing colour beside which the richness of the emerald, ruby, or saphire, would pale. The abundance of twinned crystals add much to the effect : and now, also, many fragments passed over before as less interesting put in their claim to symmetry, and shine not less brightly than those displaying facet and angle. Many hundreds of square miles

were thickly covered with this ash around the scene of the eruption, and these miracles of structural perfection doubtless abundant in every grain of it.

Dealing with the constituent minerals in the order of their abundance, the *Feldspars* first claim attention. They will be at once identified by their colourless transparency; specimens exhibiting a milky decomposed appearance, or showing diffused iron stains of brown-yellow tint being rare. In the latter case, also, a few moments' immersion in hydrofluoric acid generally shows the colour to be confined to the covering of pumice glass adhering to the surface of the crystal.

This covering of pumice, most noticeable in the feldspars, but also overspreading pyroxene crystals, is obviously the remains of a former matrix of highly vesicular glass; being occasionally even recognisable as the fragments of bubble walls; sometimes projecting along the edges of the crystal, giving a fringed appearance, or, again, overspreading the more developed faces forming a hexagonal pattern often of great beauty and regularity. The appearance, indeed, suggests at first sight such markings, cohesion figures, as are formed when two flat surfaces compressing a viscous material are suddenly separated. It will be found, however, that crystals removed from the block pumice carry with them just such remains of the matrix.

Optical examination could not safely be undertaken till this coating had been removed by hydrofluoric acid. This operation demands care, as the feldspars themselves are soon decomposed by the acid.

Two principal forms of feldspar crystals occur; a columnar and a tabular, the latter most abundantly.

That the tabular variety is in general plagioclastic is certain. Polysynthetic lines of twinning are frequently observed with polarized light, sometimes crossing at right angles. More generally these lines traverse the crystal longitudinally. Carlsbad twinning is common, extinction occuring at some 8 or 9 degrees at either side of the medial line. This form of twinning is seldom absent in crystals of the columnar variety. If such tabular crystals as exhibit this medial twinning line be considered as of the same nature as the columnar crystals, a plagioclastic character might be ascribed to the latter, as just such tabular crystals will be

met superimposed and twinned with others exhibiting undeniable plagioclastic characteristics. At the same time, many orthoclastic peculiarities are, as will be seen presently, noticeable in the columnar crystals.

Little or no cleavage is apparent in these tabular crystals. Extinction does not occur parallel to the edges of the dominant faces—apparently macropinacoids. Want of properly furnished instruments forbids the author entering at present further into the anomalies presented by these plagioclastic feldspars. They are quite insoluble in boiling hydrochloric acid—or after some days' cold digestion in the same.

The second variety, if it may be considered as such, may be described as columnar, with nearly equally developed faces seemingly at right angles to each other. Four pyramidal faces terminate one or both ends. This pyramidal termination is occasionally truncated, giving a fifth terminating face at an angle other than 90° with the zone axis of the prismatic faces. Marked rectangular cleavage on one set of these faces; direction of cleavage apparently parallel to pyramidal planes: generally a single medial twinning line on the other set of prism faces. Extinction for the first set of faces (those showing cleavage), parallel to the longitudinal axis of the crystal. For the second set, symmetrically on either side of twinning line; seldom more than 15° on either side. A specimen wanting the twinning line extinguished on these faces at 16° with the longitudinal axis; parallel to it on the adjoining faces of the same zone.

Viewed when resting on one of its longitudinal edges, characteristic border lines displaying vivid prismatic colours become apparent between crossed nicols. Polysynthetic surface striations might account for this appearance.

The photograph (Pl. xii. fig. 1), taken with nicols crossed, contains a couple of these crystals removed from the floating pumice. The crystals, adhering together, rest on their edges and display well the border lines just mentioned. (Figure 1A. Pl. xii.)

Flame tests indicate for such crystals a percentage of potassium comparable to that of orthoclase. If they, indeed, are sanadine, there is evidently a peculiarity in twinning. Although good crystals are scarce, fragments are numerous. They will be detected by their marked cleavage.

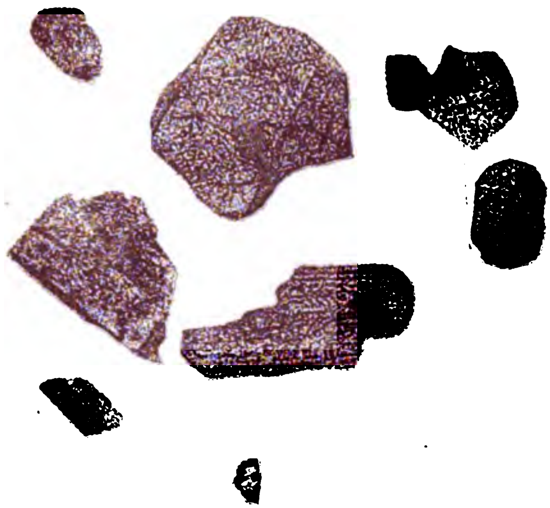
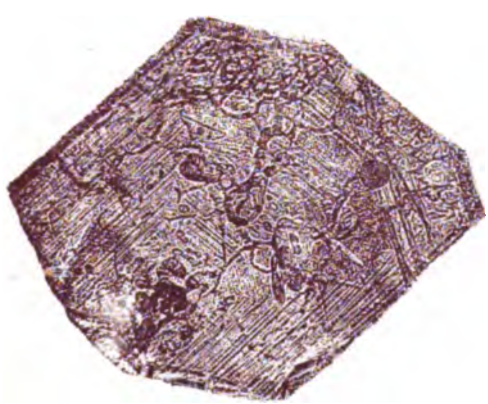


Fig.1.

Fig 2



FORSTER & CO., Photo.-Lith., DUBLIN

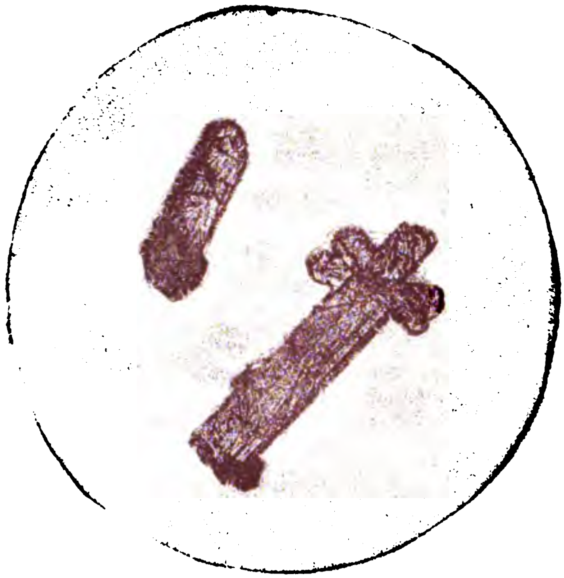
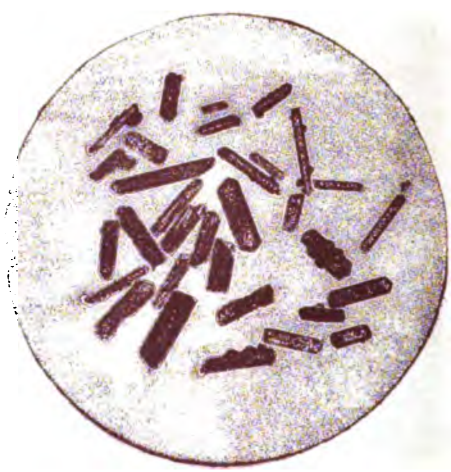


Fig 5

Fig. 4.



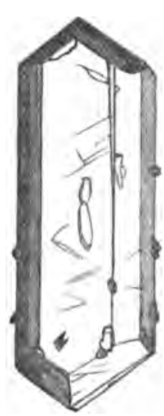
FORSTER & Co., Photo.-Lith., DUBLIN

The tabular variety is represented in the photographs by the remaining crystals shown in the photograph (Pl. xii. fig. 1), which is taken at an enlargement of about 20 diameters. A very good specimen is shown, magnified 35 diameters, in Plate xii. figure 2: enclosures, vitreous, containing crystals, will be noticed. Growth striations and the lace-like pattern of adhering-glass are also shown. The presence of growth striations or zones, very common in these feldspars is generally assumed to indicate a more or less tranquil formation.

The *Pyroxenes* are a noticeable feature in this ash. The rhombic variety is by far the most abundant, indeed the monoclinic is scarce, and present usually in badly developed or small crystals. A group of the rhombic pyroxenes is shown in Plate xiii. figure 4. Enlargement 15 diameters.

These crystals are olive-green to brown in colour; translucent. Their pleochroism is well marked, the colouration following the order assigned to *Hypersthene*, by MM. Fouqué and Lévy (Minéralogie Micrographique): that is, parallel to their principal axis dark-green, parallel to the macrodiagonal, red, with intermediate tints of brown.

This mineral will be found to extinguish parallel to its pinacoidal faces, not alone when viewed longitudinally, but also when placed with its principal axis in a vertical position between crossed nicols. Treating in this way the nearly central crystal, the one exhibiting a pointed termination at each end in the group (Pl. xiii. fig. 4), the exquisite perfection of its minute form became apparent.



This crystal, which parallel to its longitudinal axis shows pinacoidal and prismatic faces, the former dominant, shows four principal terminating planes, apparently octahedral. Two other faces, brachydomes seemingly, are well defined. Other minute faces are visible, scarcely determinable. The adjoining woodcut, a sketch of its appearance viewed in a direction inclined a little upwards, and to the left of the brachydiagonal, shows some of its faces.

The photograph (Pl. x. fig. 3) conveys but a faint idea of a very

beautiful specimen—consisting of three interpenetrating crystals. Their faces are very perfect, and extinction for each crystal is parallel to its longitudinal axis. These are soluble in hydrofluoric acid after long immersion. Just such crystals are depicted in the Minéralogie Micrographique of MM. Fouqué and Lévy, as extracted from the lavas of Santorin of 1866.

The monoclinic pyroxene, *Augite*, which so closely resembles the hypersthene in appearance will be found to be only feebly or not at all polychroic. Extinction occurs at some 30 to 37 degrees with the principal axis. This angle is stated to vary with the amount of iron present in the mineral. It is never so low as to confuse it with hornblende.

In general its crystals are of a brighter green colour than the greenest of the hypersthene. They, also, are slowly soluble in hydrofluoric acid. Crystals of hypersthene 4 mms. long were picked up: the augite rarely was found above 1 mm. in length. Similar crystals fell in Norway in a volcanic ash from Iceland (Fouqué and Lévy, *op. cit.*).

Magnetite occurs not alone abundantly as inclusions in the various crystals, but is plentiful as minute octahedrons exhibiting the usual twin forms with octahedral composition face. It shows a fine black, splendent, metallic lustre; occasionally bluish and even like that of anthracite. An electro-magnet enclosed in a long test tube was found of much service in removing it from solutions, and also in isolating the pyroxene containing this mineral.

Iron Pyrites is present in such characteristic forms as to leave little room for doubt as to its identity. It will be observed not alone in isolated fragments, little aggregations of cubes showing the striations at right angles on adjacent faces, and exhibiting the brassy lustre of pyrites, but also, imbedded in and protruding from the surface of some of the rough amorphous fragments scattered through the ash. In good light the faces of these crystals are seen to be generally pentagonal, and the crystals in fact to be principally pentagonal dodecahedrons.

It was thought that this substance might be foreign to the real constitution of the ash. The discovery, however, of a crystal with the lustre and appearance of pyrites imbedded deeply in the interior of a feldspar rendered it impossible to suppose this mineral to be merely blown up from local rocks, and so intermingled with

the ash. Remarkable deposits of it, having the appearance of infiltration along cleavage planes, occur occasionally in feldspar crystals.

Among the amorphous fragments, *Olivine* was not observed; many fragments picked up on suspicion being found to be easily soluble in hydrofluoric acid.

One of the most interesting features of this ash is the nature of the various *enclosures* in its principal minerals. They obviously give us a means of judging of their relative order of formation.

Classifying on this basis, *Magnetite* would come first in order of formation. It occurs as an inclusion in all the silicates present. It will be noticed protruding from the crystals of hypersthene in figures 3 and 4.

Pyrites might be of contemporary origin.

The *Pyroxenes* would in that case be second in order, for while including magnetite they are themselves included in the feldspars.

The *Feldspars* were probably the last minerals formed.

Vitreous inclusions are abundant, generally iron stained to a light-brown tint and enclosing the bubble which probably started their formation. Very often these inclusions are ranged parallel to the outline of the crystal; often again the vitreous mass has had the symmetrical form of the containing crystal impressed upon it. Sometimes then by their individual form, sometimes by their disposition, it is possible to judge of the former crystalline symmetry of a mere formless fragment containing such enclosures.

ADDITIONAL NOTES.

Subsequent to the reading of the foregoing, the author received many additional samples, both of the ash and of the block pumice. To the courtesy and kindness of Mr. T. Brewis the author owes these specimens in the first instance. Through information received from that gentleman samples were obtained from Captains who were in the neighbourhood of Krakatoa during the period of the eruption. To Captain Ralston, of the *Niobe*; Captain Calangich, of the *Jafet II.*; and, above all, to Captain Thomson, of the ship *Medea*, the author's best thanks are due.

The specimens of block pumice received bore, one and all, remains of marine life, incrusting the walls of the larger surface cells. Mineralogically they were not found to differ; many, however, showed veins or layers of black vesicular glass, giving a stratified appearance. The specimens, some of which are now in the Museum of Science and Art, Dublin, were picked up considerably to the south-west of the Straits of Sunda.

Dust from Batavia did not, on examination and comparison with that gathered at half that distance from Krakatoa, indicate any such sifting of its constituents in the course of its journey as M. Renard assumes in his Paper, read before the Académie Royale de Belgique (November 3, 1883). The probable explanation is that the dust was thrown so high, and in such quantities, that for many miles it was descending almost vertically, and was not, therefore, subjected to such a sifting process as it would have experienced had it been travelling horizontally.

Bearing on this point, the following computation respecting the height to which the dust, &c., was projected may be of interest:—

Captain W. Thomson heard the first explosion of Krakatoa at two o'clock on August the 26th. He was then in Lat. 5° 56′ S., Long, 106° 31′ E. Immediately after, and before the second explosion. which succeeded in ten minutes, a "black mass, rolling up, like smoke, in clouds was observed to the westward." It attained an altitude of about 12°; and, as the *Medea* will be found to have been just seventy-six miles, as the crow flies, from Krakatoa, a height of about seventeen miles is obtained for the cloud.

At five o'clock the *Medea* came to an anchor in Lat. 5° 58′ S., Long. 106° 46′ E., 89·3 miles direct from Krakatoa. The dust cloud had meanwhile been going up suddenly with each explosion; and now, as Captain Thomson cast anchor, he read the angle of elevation of the cloud, it was 40°. Obviously the column had advanced towards him; but some idea of its approach may be gathered from his subsequent statement that "the wind during the whole of the eruption was W.S.W., force between 3 and 4." Taking its velocity as twenty-one miles per hour, its advance in the three hours since the first explosion would be sixty-three miles. On this assumption the altitude of the cloud would be twenty-one miles. Other observations from other points of view would be of interest.

Captain Thomson's narrative is one of much interest from the intelligence and care displayed in his observations, although made under trying circumstances.

He records "electrical displays" round the vast column of smoke (steam) ascending from Krakatoa on the evening of the 22nd of August. These took the form of vivid lightning, flashes darting from and around the column. Showers of sand and gravel on the 23rd. The terrific explosions of the 26th and 27th are described as "shaking the ship." He was then some eighty miles off, with an intervening screen of mountainous country.

With regard to the presence of *Pyrites* in the ash, nothing was said about it by M. Renard in his original Paper (which was not, however, known to the author of these notes at the time of preparing his communication to the Royal Dublin Society); but in a note appended to a Paper appearing in *Nature* (April 17th), as the joint production of that distinguished mineralogist and of Mr. Murray, its occurrence is mentioned and dismissed as "accidental." It is, however, not alone present, free, as aggregations of cubes and dodecahedrons, but also as an inclusion in the feldspars and in the hypersthene. Again, its abundant occurrence in the ash received from various localities is observable. Fifty specimens were counted by the author in one of three slides prepared from about half a gramme of the dust from Batavia. The dust had been treated for the removal of glass, feldspars, and free magnetite. It is hard to see why, under the circumstances, it should be considered accidental.

Hematite in thin, blood-red, semi-translucent flakes occurs in the ash. It is neither cleavable perceptibly, nor elastic, and is soluble in hydrochloric acid. It shows no trace of dichroism.

The very great abundance in the ash of *Hypersthene*, compared to *Augite*, suggests that the original rock should be considered more of the nature of a hypersthene andesite than an augite andesite. In connexion with this point the results of Mr. Whitman Cross' examination of a hypersthene andesite, kindly brought under the author's notice by Professor V. Ball, are of much interest. (Bulletin of the United States' Geological Survey, No. 1, 1883.)

NOTE ADDED IN THE PRESS.

M. C. Flammarion, in the Revue d'Astronomie Populaire, July, 1884, p. 265, estimates the probable height of projection of the dust, &c., from Krakatoa as at least 20,000 metres (12½ miles).

Observations made on board the *Elizabeth*, on the comparatively insignificant explosion of May the 20th, 1883, gave 11,000 metres as the height of projection on that occasion.

XXXII.—ON AN ARGENTIFEROUS GALENITIC-BLENDE AT OVOCA. BY C. R. C. TICHBORNE, LL. D., F. C. S., &c.

[Read, October 6, 1884.]

I AM strongly of opinion that we should never lose an opportunity of bringing before the scientific public any natural product of this country which is likely to become of commercial value. The general uncertainty which appertains to all mining operations appears aggravated in Ireland, where it almost seems as if we hung upon the fringe of extensive mineral deposits. The want of smelting materials adds greatly to our difficulties. In the year 1875 I had the honour of placing before this Society[1] a specimen of a rich magnetite found in Wicklow, which at that time was unknown to the Geological Survey. The veins of this ore could be traced for some two miles or more. Consignments of the magnetite were sent to Staffordshire to be smelted, and the most flattering account of the quality of the iron obtained therefrom was returned; yet I believe this ore lies *perdu.*

I wish, on the present occasion, to bring before the Society a description of another ore of even more importance. Of this ore very little is known, and I intend to offer some speculations upon its general character. I believe that the lode may be typical of many ores, which will be found disseminated in lead mines, but of these there is no record except a short reference in the Mineral Statistics[2] for the year 1882, and also a reference to which my attention has been drawn within the last week, and subsequent to my analysis and report upon this mineral, viz.:—a paragraph in a Paper entitled, "Notes on the Ancient and Recent Mining Operations in the East Ovoca District," by P. H. Argall.[3]

The mineral I am now about to describe is known as "Bluestone," and locally in Wicklow as "Kilmacooite," from the dis-

[1] Journal of the Royal Geological Society of Ireland, vol. iv., New Ser., p. 219.

[2] Mineral Statistics of the United Kingdom of Great Britain and Ireland, for the year 1882, pp. 88 and 94.

[3] Journ. R. G. S. I., vol. v., New Ser., p. 150.

trict called Kilmacoo. It is so called in Mr. Argall's Paper. The mineral seemed to have been well known to Mr. G. H. Kinahan, whose intimate knowledge of the mineralogy of county Wicklow induced me to make inquiries of him. He gives as localities—the lode of the Magpie mine and the Connary mine, both in East Ovoca, with the Mona mine in Anglesey.

It is called "Bluestone" by the mining inspectors,[1] and it seems that about 1,240 tons of this or a similar ore are raised in the principality during the year.

The ore is a hard, steel-grey-coloured mineral, having something of the appearance of sulphide of antimony. If we except the colour, however, it does not resemble that mineral in any respect, for the structure is that of a fine-grained saccharoid mass. The ore is extremely hard, and it is broken with difficulty. In fact the rock has to be quarried by blasting. The pieces I have seen are very uniform in character, but are occasionally interspersed with crystals of pyrites and a hard, black, siliceous rock. A very slight examination will suffice to determine the fact that this mineral is a natural lode, and is not the result of an ancient working. This latter theory was once upon a time promulgated.

A piece weighed in the air 34·942 grammes: when weighed in water it gave 27·5655 grammes as the weight, so that the mineral has a specific gravity of 4·736. It will be observed that this gravity is somewhere intermediate between galena and blende. It is harder than either of those minerals. The ore, as found in Ovoca, seems, from the description given of the Welsh mineral, very much of the same character. But I have never seen a specimen from the Mona mine. As will be perceived further on, however it differs in general composition, it is much richer in silver than one of the varieties found in Wales. To quote from the Mineral Statistics, we are told that "Bluestone is an ore of zinc; average analysis—zinc, 32·15 per cent.; lead, 11·6, and 10¾ ounces of silver per ton, with a small percentage of iron and copper." But at page 88 in the same book we are informed that from the Mona mine, in Wales, they extract 5·535 ozs. from 514 tons, and that at the Morfa Du mine 5·082 ozs. from 726 tons, which represents re-

[1] Mineral Statistics of the United Kingdom of Great Britain and Ireland, for the year 1882, p. 5.

spectively 10¾ and 6·9 ozs. per ton. The following is the analysis of the argentiferous galenitic blende, so-called "Bluestone," as found at the Connary mine, E. Wicklow.

Silver,[1]	0·024
Zinc, ...	25·27
Lead, ...	25·18
Iron, ...	5·51
Manganese, ... trace,	
Antimony, ...	0·21
Arsenic, ...	0·08
Copper, ...	2·50
Aluminum, ...	0·60
Magnesium, with traces of Calcium, . .	0·02
Sulphur, ...	23·71
Silica, &c., ...	16·896
	100·000

This mineral may therefore be said to consist of

Sulphide of Zinc, ...	37·68	per cent.
Sulphide of Lead, ...	29·07	,,
Sulphide of Silver, ...	00·275	,,

and contains variable quantities of pyrites, which in this particular specimen amounts to 10 per cent.

The sulphide would represent nearly 22 per cent. of the sulphur found.

It was examined for the rarer metals by the spectroscope, but no indication of those elements could be got.

Gold was present in very small quantities. It was not estimated.

Mr. A. Ryder, of the Ovoca Mining Company, has kindly given me the following information upon the subject of the lie of the ore:—"The bluestone commences immediately to the east of a fault. It is here very rich in sulphur, and consequently of little value. We have driven on it for about 120 fathoms east, and have found that it increases in size (*i. e.* thickness of lode) and value as we go east. It also increases in value as we go deeper. It is the most 'bunchy' ore I know, growing in one place from 4 inches thick up to 3 feet 6 inches. In a distance of four fathoms I

[1] Equal to 8·6 ounces per ton (nearly 8 ounces troy).

calculate that there are about 1,000 tons in sight. The bluestone is flanked on the north by a "coal" lode, with veins of bluestone; and on the south by blue slate, and white micaceous schist, and deeper down iron pyrites."

Of course, from a commercial point of view, the amount of silver found in this ore is the most important item of the analysis. Our analysis gives rather different results from those obtained in the Welsh mines, but they do not agree at all with the analyses given in the notes to Mr. Argall's Paper. Five analyses are given, and silver is only mentioned in three out of the five, which give respectively 5, 7½, and 6 ounces per ton[1]. From reasons which we shall shortly state, we think it probable that most of the samples must have been not only poor in silver but very indefinite samples of the bluestone. It may be interesting to compare this argentiferous ore with some others which are well known and worked for their silver. The following figures are taken from Dana's Mineralogy, 5th edition:—

Argentiferous Galena, Hartz, . .	·03 to ·05 per cent.
English Galena, ...	·02 to ·06 ,,
Lead Hills, ...	·03 to ·06 ,,
American ores which are worked, run as low as	·001
Argentiferous ore from Ovoca, . .	·024

The last-named Ovoca ore compares very favourably with the rest in this list, which includes some of our great sources of silver. If we examine this mineral with the naked eye, particles of pyrites may be seen scattered through the mass in an accidental and rather erratic manner. The remainder of the mineral is, however, remarkably homogeneous, and will bear examination under the microscope by reflected light with considerable impunity. The silver exists as sulphide, because dilute sulphuric acid does not dissolve any trace of that metal from the mineral.

The actual composition of this ore brings us to the consideration of two points, viz.:—(1) How far we should be justified in considering it as a distinct mineralogical specimen; (2) The construc-

[1] Since this Paper went to Press, samples of the ore have been assayed in London, giving as high as 9 ozs. of silver per ton, and also containing 1 dwt. of gold.

tion of the names it has received. I may as well state at once that, as regards the last point, I have a strong objection to the naming of minerals after places, particularly when named after small and unknown localities. Thus Dana has named a fine-grained mixture of galena and blende Huascolite, from the province of Huasco, where it was found. Even here, I am of opinion that such terms are not desirable, if we wish to inculcate the idea that they are distinct species. A province, however, is generally well known, and it is quite different from Kilmacoo—a small place whose name is not to be found in any gazetteer or postal directory. The objection would be obvious, because until we got "Kilmacooite" recognized in the text-books upon mineralogy, the man of science would be at a loss to know what that name meant, or even to trace its connexions. There is also as great an objection to the term "Bluestone," the name used by the miners in Wales. The mineral is of a steel-grey colour, not blue; and, besides, this term is applied to a well-known chemical substance. I therefore prefer to call it argentiferous galenitic-blende.

I view the mineral as an intimate mixture of fine crystals of galena and blende, which, although they form a fine-grained saccharoid mass, apparently homogeneous to the eye, I have no hesitation in saying is composed of a mechanical mixture of microscopic crystals of two minerals. When treated with dilute nitric acid, the blende seems to be attacked first, but I do not attach much importance to this fact. If, however, we powder some of the mineral and examine it under the microscope with an inch object-glass, strongly illuminating it with transmitted light alone, we find that about two-thirds of the particles transmit light, whilst the others do not. Now, galena owes its strong metallic lustre to its great opacity, and I think we are justified in pronouncing that these last particles are galena, and that those which transmit light are blende. The finest film of galena that can be got by acting upon an alkaline solution of lead oxide with thio-urea does not transmit light, whilst blende obtained artificially by a similar method is quite transparent.

I do not think the analysis in Mr. Argall's Paper could represent very pure specimens of the minerals. It will be observed that the samples procured by me are very uniform in character, except a few isolated crystals of pyrites, which can be perceived with the eye.

In the five analyses given in Mr. Argall's Paper there is a great difference of composition: the lead varies from 7½ to 26 per cent.; the zinc from 8 to 49 per cent.; and, where estimated, the silver respectively 4, 6, and 7½ ozs. This great variation in composition is easily understood when we note the iron; for we find that one sample, marked "E," must have contained about 23 per cent. of pyrites; sample "A" 32 per cent., and sample "C" more than half pyrites.

The samples examined by me contained more silver than the highest estimation given in these analyses.

In concluding this short notice of this ore, I am tempted to quote from my report upon the Dublin International Exhibition of 1865.[1] In giving the statistics of the raising of silver in Ireland I stated that this county was a large supplier of the valuable metal, but I am afraid to make the calculation now which I did at that time. I then stated that Ireland produced 14,000 ounces of silver per annum, or 2·4 per cent. of the whole of the silver raised in the world, and its value might be estimated at £3,850 per annum, exclusive of the lead raised at the same time. If 1,000 tons of this argentiferous ore can be sighted, which represents of silver alone 8,000 ounces, how lamentable it seems that this valuable industrial resource should remain unworked—mere earth which might be transmuted into bone and sinew.

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[1] *Chemical News*, July, 21, 1865: Report upon the Dublin Exhibition, and Official Report, by C. R. C. Tichborne.

XXXIII.—NOTES ON SOME OF THE IRISH CRYSTALLINE IRON ORES. By G. H. KINAHAN, M.R.I.A., &c.

[Read, April 21, 1884].

Part I.

A question that appears to attract some attention in America at the present time is "The Genesis of the Crystalline Iron Ores"; therefore some notes on the lodes and accumulations of these ores in Ireland may be of interest.

These ores, excluding the carbonates, occur in lodes and in interbedded masses, generally lenticular and irregular. Formerly they were extensively mined in Ireland; but after the last furnace was put out, about 230 years ago, and those operations had ceased, most of the pits and accompanying works were covered up, so that the sites of many of them are now unknown. A few, however, of these ancient works have of late years been re-opened, while in other places deposits have been discovered and worked, so that from these later workings we can learn something about the nature of the deposits now in question.

Such ores are due to the decomposition of organic matter and carbonic acid. Chalybeate water contains iron, either as the sulphate or as the carbonate. When iron exists as the sulphate it has been derived from the decomposition of pyrite in the rocks through which the water has percolated; the iron in solution is oxidized on exposure to the atmosphere, and a certain proportion of it is deposited. The source of the iron, besides the sulphides, may be lodes or such like accumulations, and also the leaching out of the iron colouring matter of the rocks and clays. Le Conte thus describes the reactions that accompany the decomposition of organic matter:—

"Decomposition of organic matter is a process of oxidation. In contact with peroxide of iron (ferric oxide) it deoxidizes and becomes reduced to *protoxide* (ferrous oxide). The acids, especially carbonic acid, produced by decomposition of the organic matter, then unite with the protoxide, forming carbonate of iron. The carbonate, being soluble in water containing excess of carbonic acid, is washed

out, leaving the soil or rocks decolourized, and the iron-charged waters come up as chalybeate springs. But the ferrous carbonate rapidly oxidizes again in the presence of air, by exchanging its carbonic acid for oxygen, and returns to its former condition of ferric oxide, and is deposited."[1]

On account of these reactions, deposits of ferric oxide are found about iron springs, along the streams that flow from them, and in low places where their waters are collected. This is what usually takes place, but not always; for if the iron water accumulates in the presence of an excess of organic matter, such as peat, all the iron cannot be reoxidized, but must remain in the form of ferrous carbonate.[2]

"Thus there are two forms in which iron leached out from the soils and rocks may accumulate, viz., ferric oxide and ferrous carbonate. The former is accumulated where the organic matter is in small quantities, and consumes itself in doing the work of dissolving and carrying the latter where the organic matter is in excess."

The recent, or the more or less superficial, accumulations of iron ores may be first described. In some of the estuaries and lagoons earthy iron ore or some other ferriferous strata are deposited. In the estuary or lagoon of the Slaney (Wexford harbour) the muds are often ferriferous. In some places the ferriferous muds become richer toward the upper part, and are often covered by a thin seam or layer of ferric oxide, above which is mud. This arrangement would seem to suggest that the iron came down the Slaney, partly in solution and partly in suspension, it being supplied by the decomposition of the pyrite in the Cambro-silurian and Carboniferous argillaceous rocks and the leaching out of the colouring matter from them and the Cambrians. The lands of the "intakes" of other estuaries are often in part ferriferous, with seams or disseminated particles of iron ore in them.

It is principally during winter floods that the muds accumulate.

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[1] Other authorities ascribe it to a decomposition of the salt, the carbonic acid escaping, while water and oxygen take its place, thus forming a hydrous ferric oxide.

[2] At the bottom of some of the Irish bogs there is "stone turf," more or less impregnated with some of the sulphate or carbonate of iron, or both combined. If only the latter is present when the turf is first cut, it is not iron-stained, but after it is dried it is found to be full of little particles of the ferric oxide, the turf becoming more or less "iron-marked."

but it is during the summer heat, when the water is shallow, that the iron is deposited, partly by the ore being concentrated by evaporation, and partly by the chemical agencies already mentioned, which precipitate the soluble carbonate and sulphate, having more power to operate. For these reasons we should have first plain mud, then ferriferous muds with seams of ore, and then the same alternations repeated.

At times the iron-ore would be in excess, as whether the ore in solution be either the carbonate or the sulphate, when the waters are low and heated a quantity of the ferric oxide is deposited in the shallow pools and along the beds of the rivers and their tributaries, which stores are brought down by the first series of floods to be deposited in the estuaries or such like still waters.

The Ovoca river, county Wicklow, and such like rivers, which receive mine drainage, carry down in suspension and in solution a vast quantity of iron, to be afterwards deposited along the lower parts of their courses and in their estuaries and outside in deep water. Ferriferous river water also deposits iron in the lakes and loughauns through which it passes.

If, however, the loughauns and pools are shallow, the ore is generally washed out of them by the autumnal and winter floods. The stream that flows northward along the Maum valley, county Galway, gets quite thick and turbid during the summer heat, while a quantity of the ferric oxide is deposited in the pools, to be washed out of them and carried away by the subsequent floods.

It is a remarkable fact in connexion with the ores in the alluvium of the Irish rivers, that these old deposits are often of considerable thickness and extent, such not being the case with the recent ones. Those thick deposits are now nearly always covered with a greater or less thickness of alluvium. These peculiarities may possibly be due to the leaching out of the colouring matter of the rocks having been more active formerly; that matter having been removed to such a depth, the leaching now goes on very slowly.

Bog iron ores and ochres, although found in the alluvium of lakes and rivers, are very often associated with peat or peaty accumulations, and in general occupy hollows or nearly level surfaces; but not always, as some occur on hill slopes. When in hollows and on flats the overlying bog may be due to the iron ore having

formed an impervious floor, on which mosses, lichens, grass, heathers, &c., grow and decay. Such peat accumulations are necessarily thin, as the iron ore floor is not congenial to the rapid growth of bog.

At the present day the ore that is being formed at the surface is usually ochre, the bog iron ores being beneath greater or less thicknesses of surface accumulations. The latter is always more or less argillaceous, but in some places the surface is a rich granular ore of apparently a newer growth.

It may be observed in Ireland that where these ores occur associated with peat, the bog areas usually lie on more or less pyritous rocks, such as the black coal-measure shales, the calp shales, and black limestones, and the pyritous metamorphosed rocks; and these appear to have been in a great measure the source of the bog iron ore. This, however, is not always the case, as the iron garnets, the ferriferous micas, hornblendes, and pyroxenes, &c., in some rocks rapidly decompose, and are a considerable source of the ferric oxide; while in parts of Ulster there is a sub-metamorphosed sandstone, which, with its associated schistose rocks, supply extensive accumulations of ochre. These sandstones weather very rapidly, and in general to considerable depths—some, indeed, have all their cementing materials washed or leached out of them, leaving a residue of more or less pure sand. The normal colours of these sandstones seem to be different shades of green, or bluish-green; but these rapidly and deeply weather into a brownish iron-masked rock, with a thin dirty-white crust or surface. Besides the direct leaching of the soil or rocks, there are in places chalybeate springs which supply hydrous ferric oxide from more or less deep sources. The ochre forms a greater or less mound, or perhaps a sheet, round such springs; or may well up through boggy land, thus forming a ferriferous boggy swamp.

These bog iron ores and those allied to them, which have been briefly described, have accumulated at or near the surface. There are, however, in many of the rocks forming the surface, fissures, joints, cracks, and such like openings, into which portions of the iron in solution must flow to form deposits in cavities below the surface. Such seems to have been one of the sources in the case of the Antrim "pebble ore" described in the second part of this Paper; while in other places the leakage from younger strata seems

to have supplied the material for the iron ore now found in the underlying or older beds. Thus the iron ores in the Carboniferous limestone may have permeated downward during the formation of the Coal-measures; the Silurian iron ores during the formation of the Carboniferous rocks, &c., &c. Such a theory, however, will not account for all of the iron ore accumulations, as will appear from the brief descriptions given in the second part of some of the Irish lodes and other accumulations.

PART II.

In the first part of this Paper we drew attention to the iron ores in the surface accumulations, and their probable mode of formation; while in this it is proposed to refer more specially to the lodes, and such like, in the older rocks, accompanied with suggestions as to the possible sources from whence the iron may have come, beginning with the Tertiary *Iron Ore Measures* of the county of Antrim.

ANTRIM IRON MINES.

The Tertiary dolerites of the counties of Derry and Antrim, contain interbedded *Iron Ore Measures*. These appear to have been lacustrine deposits, which accumulated in shallow lakes or ponds of water, in hollows on ancient surfaces of the lava sheets, to be subsequently covered up by newer sheets of the dolerite. When fully developed the members of these measures are:—

1. Lithomarge, or laterite, with inliers of bole
2. Ochreous rock (Pavement).
3. Bole, or alumnious ore (*second ore*).
4. Pisolitic, or pebble ore (*first ore*).
5. Steatitic rock (Brushing).
6. Steatitic clay (Holing).
7. Alumite (or alum clay).
8. Lignite.

The lignite and alumite[1] occur only near the margins of the different basins, wholly, or in part, replacing the iron ores (3 and 4).

[1] Alumite is somewhat similar to the French clay called Bauxite, and is often so named.

No. 1. *Lithomarge.*—This is in part a methylotic rock, as it is usually more or less steatitic. It probably consisted, at first, of muds formed from the weathering of the exposed surfaces of the dolerite, its constituents having been carried into the lakes by rain, rivulets, and wind. In it there are beds and lenticular masses of bole, sometimes rich enough to be worked as iron ore; the normal lithomarge representing the wash of continuous rains or the drift of continuous or heavy winds, while the beds of bole may be the wash after long periods of drought.[1] In the lithomarge are blocks of dolerite with the outer parts decomposed to a slight depth. As these may occur at some height above the base of the lithomarge, it is not very easy to account for their appearance. (See Journal, Royal Geol. Soc. of Ireland, vol. vi., New Ser., p. 103). This theory for the formation of the lithomarge will not be received without dispute. My son, Gerrard A. Kinahan, who has examined it very carefully, believes that it cannot be a sedimentary rock, but that it is evidently a methylotic dolerite formed *in situ*. In favour of this theory he refers to the dolerite blocks in it, and the amygdaloidal portions; but apparently against this theory are the inlying beds and lentils of bole, with thin seams and bits of lignite—the amygdaloidal portions are at the surface of the underlying dolerite flow.

No. 2. *Ochreous Rock.*—This lies conformably on the lithomarge, forming its surface, and is called the pavement, because it is the floor of the iron ores. The surface of the pavement has been denuded. There seems to have been a break in the course of operations, as the measures above it were deposited under different conditions to those below it. Before, however, describing the *iron ores* (Nos. 3 and 4), we will turn our attention to the alumite and lignite.

Nos. 7 and 8. *Alumite and Lignite.*—These rocks, although placed uppermost in the list, seem to be older than the iron ores, having accumulated more or less contemporaneously with the lithomarge; they being littoral accumulating while the lithomarge was deposited in the deeper water. The alumite appears to have been originally lithomarge; but as the bog (now lignite) extended out over the

[1] As in some cases, the lignite was forming at the margin of the pools, while the lithomarge was accumulating in the deeper portions. It is probable that some of the iron ore in these boles had its origin in the leaching by the lignite of the colouring matter from the lithomarge, as seams and pieces occur in the bole, but not in the latter.

lithomarge, it leached the iron out of it, and left a residuum of alum clay; consequently the upper portions of the beds are richest, while in depth they graduate into lithomarge. At first lithomarge, alumite, and lignite gradually filled up the lakes; next, these accumulations were covered over by a flow or flows of dolerite, the steatitic rocks (Nos. 5 and 6) being the tuffose and decomposed underneath portion of the flow.

Nos. 3 and 4. *Bole* or *Alumnious Iron Ore* (2nd ore), and the *Pisolitic* or *Pebbly Ore* (1st ore).—We have next to consider how these ores accumulated between the lithomarge and dolerite. It would appear evident that they are younger than the overlying bed of dolerite, for the following reasons: first, coming up through the iron ore measures in the Glenariff mines, as mentioned by Mr. P. H. Argall,[1] there are nearly perpendicular dykes bearing about N. 15° W. These are thus described:—"These dykes may be divided into two distinct classes: first, those which stop at the roof, or *stop dykes*, and second, those that penetrate the roof, or *through dykes;* the latter invariably displace the ore measures, and bake the pisolitic seam, while the "stop dykes" neither displace nor bake the seam. The dykes that stop at the roof have a steatitic parting separating them from it, similar to that above the pisolitic ore."

Some of the "stop dykes" turn over or "splash" against the roof, which goes to prove that they are newer than it; while the "through dykes" in general can be traced up to the sheet of dolerite to which they belong. "As already stated, the pisolitic ore is neither baked nor displaced by the majority of the dykes which stop at the roof; while it is nearly always displaced and indurated by the dykes which penetrate the roof; from which it would appear that the pisolitic ore was formed prior to the latter and subsequent to the former."

The pisolitic ore has larger pisolites and is richer at the surface, the richness and size of the pisolites decreasing downward gradually, till it merges into the bole, which often is too poor to be profitably worked. The ore seam (Nos. 3 and 4) is of very irregular thickness, as in some places the roof descends until it rests on the "pavement,"

[1] Journ. R.G.S.I., vol. vi., New Ser., p. 98. Mr. Argall, late resident agent of the Glenariff mines, has examined the iron ore measures very carefully, and from his notes we will quote frequently.

or there are hollows and pot-holes in the latter, or the pisolitic ore may be absent, the roof resting on the bole, or the latter may be absent.[1]

From the facts that have been stated, it seems evident that the iron ore seam must be considerably younger than the overlying beds, and that it occupies a shrinkage fissure, this fissure being due, probably, to the drying and contraction of the lithomarge, the latter shrinking away from the steatic bottom of the dolerite; while toward the margins of the basins the lignite, in general, shrank away from the alumite, as between them a thin bed of iron ore occurs in places.[2] Into this fissure the iron ore, in part, as suggested by Mr. Argall, found its way in solution; but at the same time it was probably considerably augmented by the iron leached from the lithomarge during its change into alumite.

To me it would appear that the above is the most plausible way of accounting for the occurrence of the iron ore seam, as it lies unconformably on the "pavement," while the "stop dykes" are evidently younger than the latter, while they are older than the seam. It is also worthy of note that these "stop dykes" act very similarly to the cross courses, heaves, and the like, that cross a standing lode, as in such cases the seam is much thicker and richer at one side of the cross course than at the other. This thickening of a stranding vein at one side of cross courses has not, as yet, been satisfactorily explained; but probably it is due to a somewhat similar cause to that which thickens the horizontal Antrim lodes.

If the above theory as to the formation and growth of the horizontal iron lode is correct, it can easily be imagined how iron ores may have accumulated in other places. They may have come down in solution from the surface, or water may have leached rocks as it passed down through them, the ore subsequently being deposited in fissures and other vacancies.

Here we may draw attention to the gossan of the Ovoca mines,

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[1] From a conversation with Walter Jameson, Esq., the resident director of the Eglintoun Chemical Company's Works, Glenarm, &c., I am led to believe that his theory as to the formation of the alumite and associate beds is very similar to, if not identical with, that given above.

[2] The late W. Jory Henwood, in his description of the Cornish and other mines, has satisfactorily proved that the "lay and lay," or horizontal interstratified lodes, occupy cavities due to the irregular vertical shrinkage of beds, or parts of beds.

county Wicklow (hereafter to be described), as it shrunk away from the underlying sulphur lode, forming a horizontal fissure, which in part remained open (if we except the water that was in it), while in part it was occupied by a "gossan lode." As the latter contained minerals not a trace of which has been found in the normal lode, they suggest that the gossan lode was filled from above by foreign minerals in solution: this "gossan lode," therefore, seems to have been filled somewhat similarly to the horizontal iron lodes of the county of Antrim. In the latter case the boggy water has leached the iron out of the dolerite; while, as mentioned by Argall, in places on the surface, where the bog water comes in contact with the dolerite, beds of bog iron ore are forming. It is worthy of note that where the "through dykes" cut the pisolitic, the latter is often changed into magnetite.

Dysert and Dunamase, Queen's County, with Kilcolman and Shanagolden, County of Limerick.

At these Queen's County and Limerick localities there are old mines and veins of limonite mixed with hematite. At Dysert there are the remains of old workings that cannot be properly examined. In one place the ore seems to be in a mass of "fault-rock," and in another in a cave; and in the first place hematite is interstratified with shale. At Dunamase there is an untried vein. At Kilcolman silicious limonite occurs in an irregular mass, while at Shanagolden it is in "fault-rock." In both counties the ores occur in the Upper Limestone, close below the base of the coal-measures. The production of the iron ore may possibly have been due to the decay of the pyrites in the overlying coal-measure shales; as from this sulphate of iron would be formed and an insoluble hydrated peroxide of iron—the first to pass off in solution, the latter remaining to form the mass of ore. Or the peroxide of iron may have accumulated in the limestone caves simultaneously with the deposition of the coal-measure shales, a part of the clay also being carried down to form the shales in the ore, a part of the iron present going to form the ore and another portion the pyrite; or both processes may have occurred in turn.

Some distance to the southward a cave was discovered in the Ashford limestone quarry. It is on the same geological horizon

as the ore at Kilcolman. It dips under the coal-measures, and when first opened it contained a thick deposit of slightly ferriferous cave earth. A chalybeate stream occupies it during part of the year; but as the water does not deposit any iron in the cave, the iron must be accumulating in some subterranean cavity, or the water must come to the surface a good distance away in a chalybeate spring.

Counties of Cork and Waterford.

These counties were once famous for their iron mines; but although it is easy to find the sites of the forges and iron mills, the old workings are unknown, or cannot be examined in their present state. These mines seem to have been principally situated in the Yellow Sandstone ground, but some were in the Old Red Sandstone, and others in the Carboniferous Slate.

Some of the iron ores appeared to occur as the gossan back of copper lodes, but others have all the appearance of being independent lodes. At Glandore, county of Cork, there is a limonite back to a copper lode. This lode is remarkable, as the present "mineral channel" was first a brecciated "fault-rock," in which fissures opened that were filled by the copper lode; while, after the iron ore back had formed, a second system of fissure opened in the iron ore and the associated breccia, which are now occupied by manganese ores.

At the west end of Bear Island there is a standing lode of hematite, about eight feet wide, in the Carboniferous Slate; while elsewhere there are many smaller and usually irregular veins and strings of hematite, ofter the micaceous variety. These veins seem to be best developed in the areas where there are Intrusive Rocks.

As these veins occur below the black shales of the Carboniferous Slate group, it is possible that the ore may have had its genesis from the pyrites in them, or it may have welled up from below, it being in part the leaching of the underlying purple and red rocks of the Upper and Lower Old Red Sandstone.

It should be pointed out that there was a centre of vulcanicity in the neighbourhood of Berehaven during the accumulation of the Carboniferous Rocks, which probably had some kind of connexion with the development of the iron ore strings and veins. This action also seems to have had something to do with the accumulation of

the copper ores; because at Allihies, near the whinstone intrusions the ore is concentrated in large lodes, while elsewhere in the county of Cork the ore is in more or less small and numerous veins, or disseminated in particles in the rocks of the Yellow Sandstone (Griffith) group.

COUNTIES OF WEXFORD AND WICKLOW.

In these counties, besides the old workings, of which very little is now known, there are the iron ore backs to the pyrite lodes of the Ovoca mines; while in the purple and green Cambro-silurian slates there are irregular cakes or lentils and strings of iron ore.

Here the central member of the Cambro-silurians is made up of interstratifications of whinstones, felstones, tuffs, limestones, and schists, while above and below these there are the upper and lower red and purple slates. Many of the limestone and the calcareous schists are impregnated more or less with carbonate of iron, some, indeed, being poor iron ore (chalybite); while in the red and purple slate, but especially those of the upper zone, there are cakes or lentils of limonite and strings of hematite.

The cakes of limonite are of irregular shapes, and are probably ue to chalybeate springs that welled up while the clays were accumulating; their source being in the underlying ferriferous limestone; while the strings of hematite seem to be connected with vulcanicity, being due to steam that penetrated the cracks and joints, leaching the colouring matter out of the adjoining portion of the slates. In favour of the latter suggestion we find in other places, near intrusions of irruptive rocks, that similar strings of hematite are developed; while the newer granite (Carboniferous) causes the adjacent rocks to be "iron-masked."

At the Ovoca mines, between Ballycapple to the N.E. and Knockmohill to the S.W., the gossan backs to the lodes are, in general, ochre or limonite; while in places, but especially near heaves, the latter may be associated more or less with manganese, chalybite, and magnetite. The limonite was deposited in horizontal courses; but afterwards, when drying, it shrank away from the normal lodes, leaving vacancies, some of which remained open as large vugs, while others were filled with the "gossan lodes" already described. It is remarkable that the rocks adjoining the main mineral channel are "iron-masked" (ochreized), similar to the rocks

adjoining the intrusions of the Carboniferous (?) granite; which may indicate that these outbursts and the lode are of similar age.

Descriptions of other places in Ireland where these iron ores were worked would be little more than repetitions of what has already been said, as we could only mention of the county of Clare, that there were formerly extensive mines there; some, such as those of Ballymalone and Bealkelly, being on cakes of ore, like those in the county of Wexford—Cambro-silurians; and of the counties of Longford, Roscommon, Fermanagh and Tyrone, that the iron-workings there are in the Carboniferous Limestone, &c., &c.; that the old workings are now inaccessible, while the new lodes have not been sufficiently investigated to afford much information. We may, however, mention that at Knocksnaghty, county of Clare, and in other places, graphite, associated with iron, occurs in true veins.

XXXIV.—NOTES ON THE EARTHQUAKE THAT TOOK PLACE IN ESSEX ON THE MORNING OF APRIL 22, 1884. By G. H. KINAHAN, M.R.I.A., &c.

[Read, June 16, 1884.]

Descriptions of this earthquake have already appeared in the various daily papers and the scientific journals, but there are certain phenomena connected with it that as yet have not been described, and the principal object of this communication is to draw attention to such.

The disturbances in the area of structural damage took place between 9.15 and 9.20 a.m., April 22nd, the damaged structures being nearly all found in a tract southward of Colchester. From this tract, as a centre, the shock seems to have been felt for nearly equal distances in the surrounding country; northward it is recorded in the valley of the Humber; N. W. at Liverpool, and westward as far as Bristol. To the S. and E. its conspicuous limits were the sea coast, but slight shocks are said to have been felt east of the Straits of Dover, at Ostend and Boulogne.

The tracts in which the maximum damage was done are five in number and more or less isolated; they, in the order of intensity, are as follows:—1, Wivenhoe; 2, Peldon; 3, Abberton and Langenhoe; 4, Colchester; and 5, West Mersea; all except the first being north of the estuary of the Blackwater, and west of that of the Colne. Associated with these centres there are marginal tracts in which much damage occurred, but less than in the maximum areas, while in the adjoining county more or less damage was done at isolated places as follows:—South of the Blackwater, in the vicinity of Bradwell, and at Tillingham; to the westward at Bishop (N. W. of Maldon), Witham, Braintree, Stisted, Coggeshall, and Oldham; to the north at Nayland; to the north-eastward at Bromley Hall, Ardleigh, Dedham, and Manningtree; while eastward, toward the Naze, although it was felt, no damage seems to have been recorded.

Before proceeding further with the descriptions of the areas, it is expedient to give brief descriptions of the building materials used in this portion of Essex, and peculiarities of structure which

seem to have promoted the destruction of buildings. As to the materials, they may be generally divided as follows:—1st, brick; 2nd, stone; 3rd, lath and plaster; and 4th, shieling or wood.

1. *Brick Buildings.*—Some of these are what are called "frame houses," being bricks in wooden frames; but they are not common in the affected area, and none of those remarked appeared to be damaged. The other brick structures suffered severely, especially chimneys. The old houses in general have more traces of the quake than the new, but not always, as in North Wivenhoe both were nearly equally injured. The styles of the brick buildings seem to facilitate their coming down. Low structures have often long thin chimneys plastered against higher ones, without any binding or clamps, many of which fell down, doing considerable damage. In other places the tall houses are without gables, the chimneys coming up through a high, sloped roof, which necessitated their being of a greater or less height; many of these came down, if square, or if their greatest width was transverse to the direction of the shock. If we may judge by what can be seen outside the limits of the affected areas, many of the mouths of the chimneys, which were built of single bricks, were cracked and belled at their mouths from the heat in the flues, and consequently easily came down. Many of the walls that came down were two bricks in thickness, they having been run up without binding the outside ones to those inside; while the regularly built and bonded walls stood in all cases; the mortar used in building seems to have been of a very poor quality. Many of the cracks in these structures are in connexion with opes, such as windows and doorways: some, however, are quite independent of them. The most interesting cracks are those in the chimneys, especially where the tops of the latter are partially turned round.

2. *Stone Structures.*—The major portion of these only occur in the church towers, and in some cases are much older than the associated churches. Some of these old towers suffered severely, which cannot be much wondered at. Take as an example the Langenhoe tower, which was old, rotten, and cobbled; and here the major portion of the damage was due mostly to its fall, but not solely, as the cracks through the wall of the nave and porches are due to the earthquake. At Peldon, however, the damage was mostly due

to the quake; for, although the tower in part fell, the chancel—not more than forty years old—is much injured independently of that. Old roofs, such as that on Little Wigborough, lost their tiles. In Colchester a portion of the spire of the Congregational church came down. This, however, was not very remarkable, as the portion severed from it was a patch that had been added on account of damages from a storm.

3 and 4. *Lath and Plaster and "Shielings," or Wooden Houses.*—These are varieties of "frame houses." In the first the frames are lathed and then plastered, while in the latter the frames are covered with thin wooden slabs or slats. As these classes of houses can vibrate, especially the second, they suffered very little, except some very old ones, from which the plaster or slabs were shaken down; many of them, however, had stacks of brick chimneys that fell and did considerable damage.

Geology of the Areas of Structural Destruction.

From the geological map by my colleague, Mr. W. H. Dalton, we learn that these different areas are on, or at the margin of, exposures of the London clay, while rarely has any damage occurred on the later accumulations. The destruction on it, however, is confined to more or less small, limited, defined tracts. In connexion with the geology, it may be mentioned that the evidence would seem to suggest that the earthquake shock did not travel from one of the intensely affected areas to another, but that it was in action in all at one and the same time, travelling in each in more or less different directions, which, as pointed out by Dr. Taylor, of Ipswich, seems to be due to the diversion of the shock by lines of faults or breaks in the continuity of the strata.

Wivenhoe.—This lies immediately N.E. of a part of the estuary of the Colne, the intense shock having affected a very small tract which is margined to the southward by the break of the Colne river valley (N. 75° W.); and adjoining this line the shock was very severe, while it gradually decreased in intensity towards the N.E., as a mile to the N.E. the houses in the north portion of the village of Wivenhoe Cross were not injured. Eastward, in the Alresford district, the damage was very slight compared to that at Wivenhoe; also to the west of the water at Rowhedge, although in

the northern portion of the latter a good number of houses were more or less wrecked. It is worthy of note that the railway cutting appears to have modified the shock, as the houses adjoining it, both to the south and north, scarcely suffered. Here, as previously mentioned, the new houses were wrecked as much as the old, especially those near the Hall, to the north of the railway.

The most ruined portion of this village is on the narrow outcrop of London clay at the margin of the glacial drift; but at the same time all the other structures that were injured are on the latter, and some of these received considerable damage.

The shock evidently came from the N.N.E.; but when it met the break of the Colne river valley it seems to have recoiled, or in part collided along it, thus causing additional destruction in the vicinity of the river. The narrow band of London clay also appears to have had some sort of connexion with the maximum damage done, as in places it appears to have travelled in it under the later accumulations. This is also suggested farther northward, as between Colchester and Ardleigh there are narrow tongues of London clay, the houses on which were injured while those on the newer gravel were not, except in one instance.

Peldon, Abberton, and Langenhoe District.

In this locality the structural damages occurred in a rather considerable-sized N.E. and S.W. tract, between the marches of the Mersea and Pyfleet creeks on the S.E. and the valley of the Lagen river on the N.W., and extending from Fingrinhoe on the N.E. to Virley on the S.W. To the N.E., at Hornwood, the damages were slight, although it is close to both Wivenhoe and Rowhedge, but divided from them respectively by the breaks of the Colne and Roman rivers valleys; while to the S.W. the destructive action gradually decreased until eventually it died out before Tolleshunt Knight was reached. At Virley the action is interesting, as this village is only separated from Salcot by a small narrow E. and W. creek, yet the houses in Virley, most of them comparatively new, are damaged; while those in Salcot, which are old and frail, were not affected—all this tract, except a small portion near Fingrinhoe, is on the London clay. To the southward of Virley, in a line running about E. S. E. by E. from Tolles-

hunt Darcy, a little damage was done, the injured structures being on the margin of the London clay.

Peldon, Area of excessive Damage.—This extends west by north and east by south, being bounded northward and southward by small stream valleys, the maximum damages having taken place at the southern and western margins. In this area the effects would appear to suggest that the shock had a sort of rotary motion; the main direction, however, seems to have been southward, and the concussion against the lines that form the southern and western boundaries appears to have caused the great destruction in those places. The twist in the direction of the shock in the vicinity of the southern boundary is exemplified by the twist in the chimney of Strood mill, and in the damages that have been described as happening to Dr. Green's house in the same vicinity. A well near Peldon is said to have become quite muddy.

Abberton and Langenhoe Area of excessive Damages.—This tract extends about N.N.E. and S.S.W., its southern boundary being the small stream valley that bounds the Peldon area on the northward. The maximum damage seems to have happened in the vicinity of Abberton, where the well is said to have remained muddy for a few days. The shock appears to have been rotary, but the general direction would seem to have been from the southeastward, having concussion shocks from the boundaries, which might account for the rotary appearance and the twisted action observed at Langenhoe, where the church and glebe house suffered considerably.

To the N.E., at Fingrinhoe and Frenchman's Lane, the structural damages margin the tract of glacial drift previously referred to.

Colchester Area.—The maximum damage occurred in a narrow nearly east and west strip along the south Roman wall, from Head Gate to the valley of the Colne. South of this strip very little damage was done, while northward it rapidly decreased, scarcely any damage occurring north of the Colne river. From the geological map by Mr. Dalton we learn that a narrow outcrop of London clay occurs along the south wall, widening a little towards the eastward, the excessive damage following this widening. North of this outcrop the damaged structures are on the glacial drift, while on the alluvium at East Bridge there are some

houses wrecked, although to the southward, at Hythe Bridge, houses similarly situated are uninjured.[1] The houses at East Bridge are remarkable, because the direction of the shock seems to have turned southwestward at the river, while elsewhere in Colchester it seems to have gone nearly N. (N. by E.). The water in the artesian well that supplies Colchester rose, after the quake, seven feet, which height it has still kept up. This possibly is due to the earthquake rupturing a dyke, or even a thin parting of "fault-rock," and thereby adding an additional area of chalk to that from which the water was previously drawn.

Scarcely any damage was done in the western portion and suburb of Colchester, while southward to the valley of the Roman river the isolated houses, &c., damaged, are nearly always on small tongues of London clay, the principal exceptions being at Roman Hill, Middlewick, and Cockwort. East of the Colne river valley, as elsewhere when the boundary or break of an excessively damaged area is passed, very little damage occurs, the greatest being in the village of Greensted and Wivenhoe Park. These damaged areas are on London clay, as also most of those to the N.E. along the Crockleford stream valley.

West Mersea Area.—This portion of the island of Mersea seems to have been given more importance than it is entitled to, on account of the cracks that opened in it and the springs that came up, while in reality the damage done was less than that in the country to the northward, being also altogether confined to a small tract. To the S.W. of the island, along the sea road, near a slight drift escarpment to the N. and N.W. of SS. Peter and Paul's Well, an E. and W. crack opened. It is said to have been wide enough to put in your open hand and to have been over two yards deep. In appearance it was very like the cracks not uncommon near the escarpments of drift cliffs. The well is at the base of the cliff, at the margin of the alluvial flat, and has remarkably clear water, which is said to have risen and become quite muddy, while a similar phenomenon took place in the pump well of the Coastguard Station, a little to the north. To the N. E. of this, at Crossfarm, a second E. and W. crack is said to have opened; while in two places along it water spouted up—at one place

[1] Some houses on the alluvium at Wivenhoe are injured.

discoloured with red sand, and at the other with yellow. These springs are said by the tenant to have lasted for about half an hour. About thirty-two paces to the north of this line the water in a well rose two feet and became quite muddy. All the people from whom inquiries were made agreed in saying that the waters in these different places had no peculiar taste or smell.

The shock seems to have come from the N.N.E., and was described by a boatman coming north across the Blackwater estuary, as having first taken the stern of his boat as if he had run on a mud bank, and then nearly twisted the rudder out of his hand, as if he had cleared the bank. This statement of the boatman as to the direction of the shock was confirmed by the Chief Boatman in charge of the Coastguard Station and others.

Of the exact time at which the shock was felt at each place nothing satisfactory could be learned, as outside Colchester very few people could say their clocks were right; in each village, and often in the one house, there being fifteen minutes or more between the times registered by the clocks. The bearings of the walls on which those that stopped hung indicate the direction of the shock.

The cracks in the walls are also very unsatisfactory, as those in one building may dip in different directions or even be at right angles to one another; thus between Peldon and Strood Mill the majority bear nearly E. and W. (west by north), and dip northward at 40°; but some of these dip southward while those of another system run nearly N. and S., and dip eastward at 30°; also in the Abberton and Langenhoe area they are most irregular, both as to direction and dip. At Colchester in general the cracks bear nearly E. and W., but some do not; most of them have a more or less high angle of dip, and at Wivenhoe the greater number are parallel to the river bed (N.N.W. and S.S.E.). The cracks in general are from $\frac{1}{4}$ to $\frac{1}{2}$ an inch wide, but in a few places, such as in the Peldon area, they are wider. In no place could I find a trace of the walls having moved up and down along the cracks.

The inhabitants of the different areas of greatest structural damage appear to have been so scared that they cannot tell if there was more than one shock. At the following places, however, two or more shocks are said to have been felt:—Mark Tay, 2; Maldon, 3; Walton-on-the-Naze, 2; Ipswich, 3 (where it is also

said a shock was felt at 11.8 p.m.); Sudbury, 2; and Colchester, 2 or 3.

In the Peldon area, it is stated by Dr. Green of Croagh and the people of the village of Peldon, that a slight quake was felt about six or eight weeks before April 22.

SUMMARY.

The area of structural damage was limited, but in the country surrounding it the shock was felt for considerable distances.

In the area of structural damages there were smaller areas in which the effects were greatest. These smaller areas are distinctly margined at two or more sides by well-marked lines, while at one or two of these lines the maximum damage in each occurred. The greatest damage was done in the Peldon and Abberton areas.

In the areas of greatest effect, the shock travelled in different directions; yet, in all, the shock appears to have occurred at the same moment.

The geological formations in the area of structural damage are "London clay," "glacial drift," and "alluvium." In two places, Eastbridge, Colchester, and at Wivenhoe, damages were observed on the latter, while from the north portion of Wivenhoe to Alresford, and in the northern part of Colchester, damages occur on the glacial drift; but elsewhere all damages, especially the greater ones, are found on the London clay; while nearly invariably the destruction ceased at the margin of the later accumulation.

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NEW SERIES.

END OF VOL. VI.

APPENDIX.

LIST OF FELLOWS, CORRECTED TO FEBRUARY 16, 1885.

Fellows are requested to correct errors in this List, by Letter to the REV. DR. HAUGHTON, Treasurer, Trinity College, Dublin.

OFFICERS OF THE SOCIETY FOR THE YEAR 1885–86.

(*Elected*, 16*th of February*, 1885.)

PRESIDENT.—Professor J. P. O'Reilly, C.E., M.R.I.A.

VICE-PRESIDENTS.—Earl of Enniskillen, F.R.S; Professor E. Hull, LL.D., F.R.S.; G. H. Kinahan, M.R.I.A.; Rev. Samuel Haughton, M.D., D.C.L., F.R.S.; Professor V. Ball, M.A., F.R.S.

TREASURERS.—Rev. Samuel Haughton, M.D., D.C.L., F.R.S.; T. Maxwell Hutton, M.R.I.A.

SECRETARIES.—Hugh Leonard, F.G.S., M.R.I.A; Professor W. J. Sollas, M.A., D.Sc.

COUNCIL.—Rev. Maxwell H. Close, M.A., F.G.S.; Professor Robert Crawford, M.A., M.E.; W. J. Chetwode Crawley, LL.D.; W. Frazer, F.R.C.S.I.; Professor A. C. Haddon, M.A., F.Z.S.; Edward Hardman, F.C.S.; Sir Robert Kane, LL.D., F.R.S.; Professor W. R. M'Nab, M.D.; George Porte, M.R.I.A.; Professor J. Emerson Reynolds, M.D., F.R.S.; R. Glascott Symes, M.A., F.G.S.; B. B. Stoney, C.E., F.R.S., M.R.I.A.; C. R. C. Tichborne, Ph.D., M.R.I.A.; A. B. Wynne, F.G.S.

HONORARY FELLOWS.

Elected.

1865. Burton, Captain R. F., *Royal Geographical Society*, 1, *Savile-row, London; British Consul, Trieste.*

1861. Daubrée, Gabriel Auguste, Memb. de l'Instit. de France; For. Mem. R.S.; Honorary Director of the School of Mines; and Professor of Geology in the Museum of Natural History, Paris; *Paris.*

1865. Des Cloizeaux, Alfred L. O., Memb. de l'Instit. de France; For. Mem. R.S.; Professor of Mineralogy in the Museum of Natural History, Paris; *Paris.*

Elected.

1880. De Lapparent, A., Président de la Société Géologique de France, 3, *Rue de Tilsitt, Paris*

1861. Geinitz, Hans Bruno, Ph.D.; Professor of Mineralogy and Geology in the University of Dresden; For. Memb. G.S.; *Dresden.*

1863. Hunt, Dr. T. Sterry, F.R.S., D.Sc., LL.D., *Montreal, Canada.*

1873. Jones, Professor T. Rupert, F.R.S., 10, *Uverdale-road, King's-road, Chelsea, London, S.W.*

1861. Koninck, Laurent-Guillaume de, M.D.; Professor of Chemistry and Palæontology in the University of Liége; For. Memb. G.S.; *Liége.*

1861. M'Clintock, Admiral Sir Francis Leopold, R.N., C.B., F.R.S., D.C.L., LL.D., 29, *Kensington Gate, London, W.*

HONORARY CORRESPONDING FELLOWS.

1859. Gordon, John, C. E., *India.*

1859. Hargrave, Henry J. B., C. E., *India.*

1858. Kingsmill, Thomas W., *Shanghai, China.*

ORDINARY FELLOWS.

[*The sign* * *is prefixed to the names of Fellows who have paid Life Composition.*]

[*The sign* † *is prefixed to the names of Fellows who have paid Half Life Composition.**]

[*The names of Annual Fellows are printed in Italics.*]

1853. *Allen, Richard Purdy, F.G.S., 48, *Pall Mall, London, S. W.*

1868. †Backhouse, Marmaduke, B.A., C.E., 10, *Harcourt-terrace, Dublin.*

1879. †Barter, Rev. John Beaufort Berkeley, M.R.I.A., *Benmore Rectory, Enniskillen.*

1875. †Boot, John Thomas, *Hucknall, Mansfield.*

1873. †Broughton, Frederick R., LL.D., *Hamilton, Ontario.*

1878. *Ball, Valentine*, M.A., F.R.S., 1, *Raglan-road, Dublin.*

1861. *Barrington, E. E.*, M.B., *Enniskerry.*

1862. *Barton, Henry M.*, 4, *Foster-place;* and *Stone House, Stillorgan-road, Booterstown.*

1883. *Brown, Thomas*, 48, *Serpentine-avenue, Sandymount, Co. Dublin.*

1883. *Bell, Hamilton*, 46, *North Great George's-street, Dublin.*

1884. *Beatty, Robert Allen*, B.A., 78, *University-street, Belfast.*

1862. *Close, Rev. Maxwell, H.*, M.A., F.G.S., 40, *Lower Baggot-street, Dublin.*

1874. *Crawley, W. J. Chetwode*, LL.D., 3 & 4, *Ely-place*, and *Somerset House, Temple-road, Rathmines, Co. Dublin.*

1862. †Carter, T. S., *Watlington Park, Watlington, Oxfordshire.*

1867. †Clark, George R., C.E., *Northern Bengal State Railway, Parbatipur, Dinagepore, Bengal.*

1854. †Clemes, John.

1870. †Cooke, Samuel, C.E., *Civil Engineering College, Poona, Bombay.*

1873. †Cooper, Joseph Alexander, M.D., *Civil Surgeon of Hissar Hissar, Bengal.*

1873. †Cox, Charles C., *Ashby House School, Walsall.*

1857. †Crawford, Robert, M.A., M.E., *Professor of Engineering, Dublin University*, 37, *Trinity College.*

1861. †Crosbie, William, *Ardfert Abbey, Ardfert, Tralee.*

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* EXTRACT FROM BY-LAWS.

"Any person not residing for more than sixty-three days in each year within twenty miles of Dublin shall be a Fellow for Life, or until he comes to reside within the above distance, on paying to the Treasurers the sum of £5 5*s*.

"Any non-resident Life Fellow who shall reside within twenty miles of Dublin for more than sixty-three days in any one year shall cease to be a Fellow, unless he shall either pay an additional composition of £5 5*s*., or shall pay a subscription of 10*s*. 6*d*. for each year in which he shall so reside for more than sixty-three days.

Elected.
1868. †Cruise, Richard J., *Geological Survey, Sandymount.*
1873. †Cunningham, R. O., M.D. Edin., *Professor of Natural History, Queen's College, Belfast.*
1857. *Carson, Rev. Joseph, D.D., S.F.T.C.D., *Trinity College*, and 18, *Fitzwilliam-place, Dublin.*
1857. *Dowse, Rt. Hon. Baron, 38, *Mountjoy-square, South.*
1872. *Durham, J. S. W., *Rosenthal, Torquay, Devon.*
1874. †Devine, Thomas, F.G.S., *Deputy Surveyor-General for Ontario, Toronto, Canada.*
1873. †Dobbs, Joseph, *Coolbaun, Castlecomer, Kilkenny.*
1880. †Douglas, Lithgow Robert A., *North Brink, Wisbech, Cambridgeshire.*
1880. †Dowdall, Rev. Launcelot Downing Dowdall, M.A. (Dubl. and Oxon.), 9, *King's Parade, Clifton.*
1866. †Duffin, W. E. L'Estrange, C.E., *County Surveyor's Office, Limerick.*
1861. †Dunalley, Lord, *Kilboy, Nenagh.*
1876. †Dunscombe, Clement, M.A., C.E., *Public Offices, Derby.*
1884. †Doherty, Francis, *Kilmoriarty, Portadown.*
1866. †Ellis, R. H.
1871. †Emerson, Rev. J. M., 99, *Marlborough-road, Donnybrook, Co. Dublin.*
1869. †Enniskillen, Earl of, F.R.S., LL.D., D.C.L., M.R.I.A., *Florence Court, Enniskillen.*
1872. *Egan, Frederick Wm.*, B.A., *Geological Survey*, 44, *Frankfort-avenue, Rathgar.*
1876. *Fitt, Decimus*, C.E., *care of Messrs. Courtney & Stephens*, 2, *Blackhall-place, Dublin.*
1866. *Foot, A. W.*, M.D., 49, *Lower Leeson-street, Dublin.*
1861. *Fottrell, Edward, J.P., 61, *Palmerston-road, Rathmines, Co. Dublin.*
1862. *Fraser, W., F.R.C.S.I., 20, *Harcourt-street, Dublin*
1858. *Gages, Alphonse Chev. L. H.*, M.R.I.A, 51, *Stephen's-green, Dublin.*
1872. †Gore, J. E., F.R.A.S., M.R.I.A., *Beltra, Ballisodare.*
1883. *Grainger, Rev. John* (Canon), D.D., M.R.I.A., *Broughshane, county Antrim.*
1857. *Greene, Sir John Ball, C.B., Commissioner of Valuation, 6, *Ely-place, Dublin.*
1848. *Haughton, Rev. Samuel, M.D., D.C.L., F.R.S., S.F.T.C.D., 40, *Trinity College*, and 31, *Upper Baggot-street.*
1862. *Henry, Frederick Hugh, J.P., *Lodge Park, Straffan, county Kildare.*
1850. *Hone, Nathaniel, *St. Doulough's, county Dublin.*
1871. †Hardman, E. T., 14, *Hume-street.*
1861. †Harte, W., C.E., *Donegal County Surveyor, Office, Londonderry.*
1856. †Haughton, Colonel John, R.A., *Halifax, Nova Scotia.*
1850. †Head, Henry H., M.D., M.R.I.A., 7, *Fitzwilliam-square.*
1858. †Hill, J., C.E., M.R.I.A., *Ennis, county Clare.*
1862. †Hudson, R., F.R.S., F.L.S., *Clapham Common, London.*
1881. *Haddon, Alfred Cort*, M.A., F.Z.S., Professor of Zoology in the Royal College of Science for Ireland, 4, *Willow Bank, Kingstown.*
188 . *Heron, Robert, Junr., Dawson Court, Blackrock.*
1857. *Hampton, Thomas*, C.E., 6, *Ely-place, Dublin.*
1870. *Hull, Edward*, M.A., LL.D., F.R.S., Director, Geological Survey of Ireland, 14, *Hume-street, Dublin.*
1865. *Hutton, T. M.*, M.R.I.A., 118, *Summer-hill, Dublin.*
1881. *Houston, Fred. H.*, M.R.I.A., 31, *Mountjoy-square, Dublin.*
1871. †Kelly, G. N. H., C.E., *Highfield, North Circular-road, Dublin.*
1862. †Kinahan, G., J.P., *Roebuck Park, Dundrum, county Dublin.*
1853. †Kinahan, George H., M.R.I.A., *Ramelton, county Donegal.*
1862. †Kincaid, Joseph, Jun., C.E.
1866. *Knapp, W. H.*, M.A., C.E., *Wellington Lodge, York-street, Kingstown.*
1867. *Kane, Sir Robert, LL.D., F.R.S., M.R.I.A., *Fortlands, Killiney, county Dublin.*
1866. *Lalor, J. J., J.P., *Dromartin Castle, Dundrum.*
1856. *Lentaigne, Sir John, C.B., M.D., M.R.I.A., *Great Denmark-street, Dublin.*
1874. †Laurence, Rev. Chas., *Lisreaghan, Laurencetown, county Galway.*

Elected.
1858. †Leach, Lieut.-Colonel, R.E., M.R.I.A., 3, *St. James's-square, London, S.W.*
1868. †Leonard, Hugh, F.G.S., M.R.I.A., 2, *Herbert-terrace, Blackrock, county Dublin.*
1875 †Lilley, Rev. Charles, M.A., *Head Master of Ware Grammar School, Ware, Herts.*
1840. †Lindsay, Henry L., C.E., *Melbourne, care of J. Bower, Esq., C.E.*, 28, *South Frederick-street.*
1876. *Mayne, Thomas, M.P., 5, *Williams' Park, Rathmines, Dublin.*
1846. *Murray, B. B., *County Survey Office, Downshire-road, Newry.*
1867. †Meadows, J. M'Carthy, C.E., *Clogh Colliery, Castlecomer.*
1874. †Meadows, Joseph, Jun., *Thornville, county Wexford.*
1840. †Montgomery, James E.
1856. †Moloney, C. P., *Capt. 25th Regiment, Madras N. I., per Messrs. Grindlay & Co.*, 3, *Cornhill, London.*
1856. †Medlicott, Henry B., F.G.S., *Geological Survey of India, per Mr. H. S. King, Cornhill, London, E.C.*
1857. †M'Ivor, Rev. James, D.D., M.R.I.A., *Rectory, Moyle, Newtownstewart, county Tyrone.*
1865. †Morton, G. H., F.G.S., 4, *Onslow-road, Elm Park, Liverpool.*
1881. *More, Alexander Goodman*, F.L.S., M.R.I.A., Director of the Natural History Museum, *Leinster House*, and 92, *Leinster-road, Rathmines, county Dublin.*
1863. *Macalister, A.*, M.D., F.R.S., Fellow of St. John's College, and Professor of Anatomy in the University of Cambridge, *Strathmore House, Hervey-road, Cambridge.*
1878. *M'Henry, Alexander, Geological Survey Office, Rathmullen, Co. Donegal*, and 54, *Serpentine-avenue.*
1863. *M'Donnell, Alexander*, C.E., M.R.I.A., *Saltwell Hall, Gateshead-on-Tyne.*
1851. *M'Donnell, John*, M.D., M.R.I.A., 32, *Upper Fitzwilliam-street.*
1876. *M'Nab, W. R.*, M.D., *Professor of Botany, Royal College of Science for Ireland*, and *The Mall, St. Laurence-road, Clontarf.*
1883. *Moore, Rev. Donald, Billy Rectory, Bushmills, county Antrim.*
1884. *Murdoch, D. B.*, L.R.C.P., Edinb., 7, *Linden Gardens, High-road, Chiswick, London, W.*
1845. †Neville, John, C.E., M.R.I.A., *Roden-place, Dundalk.*
1870. †Nicolls, Thomas J., Inst. C.E., 3, *Maxwell Terrace, Pollokshields, Glasgow.*
1868. †Nolan, Joseph, M.R.I.A., 21, *Frankfort-avenue, Rathgar.*
1872. *O'Brien, William, *Ailesbury House, Merrion, county Dublin.*
1881. *O'Reilly, Joseph P.*, C.E., M.R.I.A., Professor of Mining and Mineralogy, Royal College of Science for Ireland, 58, *Park-avenue, Sandymount, county Dublin.*
1874. *Porte, George* M.R.I.A., 43, *Great Brunswick-street*, and *Calpe, Blackrock, county Dublin.*
1857. *Porter, William, C.E.
1832. †Renny, Henry L., R.E., *Canada.*
1870. †Rigby, Jason, C. E.
1873. †Rowney, Professor T., Ph.D., *Queen's College, Galway.*
1864. *Reynolds, J. Emerson*, M.D., F.R.S., Professor of Chemistry, Dublin University, 62, *Morehampton-road, Donnybrook, county Dublin.*
1857. *Reeves, Robert S.*, M.A., 5, *Fitzwilliam-place, Dublin.*
1861. *Roberts, W. G.*, 7, *Cornwallis-terrace, Clifton, Bristol.*
1875. *Ross, George M.*
1862. *Rowan, D. J.*, C.E., *Mount Haigh, Kingstown.*
1864. *Symes, Richard Glascott, M.A., F.G.S., *Portrush, county Antrim.*
1872. †Sharpe, R. W.
1868. †Siree, P. H., C.E.
1854. †Smyth, W. W., M.A., F.R.S., 28, *Jermyn-street, London.*
1865. †Steele, Rev. W., *Portora Royal School, Enniskillen.*
1871. †Sturman, Dr. E. A., 42 *and* 44 *Ennis-road, Strand Green-road, Finsbury-park Station, London, W.*
1861. *Stoney, Bindon B.*, C.E., M.A., F.R.S., 14, *Elgin-road, Dublin.*

Elected.
1875. †Scholfield, Amos, M.A., LL.D., *Cardiff, S.W.*
1854. †Scott, R. H., M.A., F.R.S., *Meteorological Office*, 116, *Victoria-street, London.*
1884. *Sollas, W. J.*, M.A., LL.D., D.Sc., Professor of Geology and Mineralogy, Dublin University, 4, *Clyde-road, Dublin.*
1857. †Tate, Alexander, C.E., *Queen's Elms, Belfast.*
1870. †Taylor, J. E., F.G.S., F.L.S., *Museum, Ipswich.*
1866. †Townsend, H. W., *Clonakilty.*
1871. †Traill, William A., M.A.I., *Bushmills, county Antrim.*
1873. †Trench, J. Townsend, J.P., *Lansdowne Lodge, Kenmare.*
1875. *Taylor, F. C., Summerleaze Collegiate School, East Harptree, near Bristol.*
1880. *Taylor, John F., Middle Temple, London*, and 36, *Kildare-street.*
1864. *Tichborne, C. R. C.*, Ph.D., F.C.S., *Apothecaries' Hall, Mary-street*, or 15, *North Great George's-street.*
1851. *Whitty, Rev. John Irvine, LL.D.
1863. *Westropp, W. H. S.*, M.R.I.A., *Lisdoonvarna, county Clare.*
1866. †Wall, H. P., *Portarlington.*
1864. †Waller, G. A.
1880. †Watts, Robert George, M.D., 5, *Bulstrode-street, Cavendish-square, London, W.*
1853. †Webster, William B.
1871. †Weldon, Major Frank, per Messrs. Grindlay & Co., 3, *Cornhill, London.*
1872. †White, Henry V., C.E., *County Surveyor, Portarlington.*
1872. †White, John N., M.R.I.A., *Rocklands, Waterford.*
1876. †Whiston, William, M.A., *Collegiate Academy, Chapel-Chorlton, near Newcastle, Staffordshire.*
1861. †Whitley, C. J., *Brisbane, Queensland.*
1846. †Wilson, Walter.
1864. †Wright, Joseph, *Cliftonville, Antrim-road, Belfast.*
1854. †Wyley, Andrew.
1857. †Wynne, Arthur B., F.G.S., *Geological Survey*, 14, *Hume-street, Dublin*, and 4, *Crosthwaite-park, Kingstown.*

SOCIETIES AND INSTITUTIONS TO WHICH THE JOURNAL OF THE ROYAL GEOLOGICAL SOCIETY OF IRELAND IS SENT.

ABERDEEN ..	University Library.
ALBANY ..	State Library, New York.
AMSTERDAM ..	Royal Academy of Sciences.
ANTWERP ..	Palæontological Society of Belgium.
BELFAST ..	Queen's College Library.
	Naturalists' Field Club.
BERLIN ..	Royal Prussian Academy of Sciences.
	German Geographical Society.
	German Geological Society, per Besserche Buchhandlung, *Behrenstrasse*, 7, *Berlin.*
BOLOGNA ..	Academy of Sciences of the Institute.
BORDEAUX ..	Society of Physical and Natural Sciences.
BOSTON ..	American Academy of Arts and Sciences.
	Natural History Society.
BRISTOL ..	Institution for the Advancement of Science, Literature, and the Arts.
BRÜNN ..	Natural History Association.
BRUSSELS ..	Royal Academy of Sciences, Letters, and Fine Arts of Belgium.
BUDAPEST ..	Royal Geological Institution of Hungary.
CAEN	Linnæan Society of Normandy.
CALCUTTA ..	Asiatic Society.
	Public Library.
	Geological Survey of India.

CAMBRIDGE ..	Philosophical Society.
	Trinity College Library.
CANTERBURY, NEW ZEALAND ..	Geological Survey.
CAMBRIDGE, MASS., U. S. A. ..	Editor of Science.
COPENHAGEN	Royal Danish Academy of Science and Letters.
CORK	Queen's College Library.
	Royal Institution.
DIJON	Academy of Sciences, Arts, and Literature.
DRESDEN ..	"Isis" Natural History Society.
DUBLIN ..	Royal College of Surgeons' Library.
	Royal Irish Academy.
	University Library.
	Royal Dublin Society.
	Ordnance Survey Library.
	Geological Survey of Ireland.
	Institution of Civil Engineers.
EDINBURGH ..	Royal Society of Edinburgh.
	Edinburgh Geological Society.
	Royal Scottish Society of Arts.
	University Library.
	Society of Antiquaries.
	Advocates' Library.
	Royal Physical Society.
ESSEX ..	Epping Forest and County of Essex Naturalists' Field Club. A. Lockyer, Esq., Hon. Librarian, *Tavistock-road, Snaresbrook*.
FALMOUTH ..	Royal Cornwall Polytechnic Society.
FLORENCE ..	Italian Society of Sciences.
GALWAY ..	Queen's College Library.
GENEVA ..	Society of Physics and Natural History.
GLASGOW ..	University.
	Glasgow Geological Society.
GÖTTINGEN ..	University.
HALLE ..	Natural History Association for Saxony and Thüringia, per Antons Buchhandlung, *Halle*.
HANAU ..	Upper-Hessian Society of Natural and Medical Science.
HANOVER ..	Royal Library.
HARLEM ..	Dutch Society of Exact and Natural Sciences.
	Teyler Institution.
KILKENNY ..	Archæological Association of Ireland.
KÖNIGSBERG	Royal Physical and Economical Society.
LAUSANNE ..	Vaudian Society of Natural Sciences.
LEEDS ..	Geological and Polytechnic Society of the West Riding of Yorkshire.
	Philosophical and Literary Society.
LEIPSIC ..	Royal Saxon Society of Sciences.
	University.
LIVERPOOL ..	Literary and Philosophical Society.
	Historic Society of Lancashire and Cheshire.
	Geological Society, The Royal Institution, *Colquitt-street*.
LONDON ..	Geological Survey, *Jermyn-street*.
	British Museum.
	Society of Arts, *John-street, Adelphi*.
	Royal Institution, *Albemarle-street*.
	Royal Society, *Burlington House*.
	Geological Society, *Burlington House*.
	Linnæan Society, *Burlington House*.
	Royal Geographical Society, 15, *Whitehall-place*.
	Civil Engineers, Institution of, 25, *Great George-street, Westminster*.
	Royal Asiatic Society, 22, *Albemarle-street*.

m.

	Royal College of Surgeons, *Lincoln's Inn.*
	Zoological Society, 11, *Hanover-square.*
	Geological Magazine, Editor of.
	Athenæum, 14, *Wellington-street, Strand, London, W. C.*
	Anthropological Society, 4, *St. Martin's-place, London, W. C.*
LYONS	Society of Agriculture, Natural History, and Useful Arts.
	Linnæan Society.
	Academy of Sciences, Literature, and Arts, per Treuttel & Wurtz, 19, *Rue de Lille, Paris.*
MADRID ..	Royal Academy of Sciences.
	Geographical Society.
MANCHESTER	Literary and Philosophical Society of.
	Manchester Geological Society.
MELBOURNE	Philosophical Institute of Victoria.
	Public Library, per Bain and Co., 1, *Haymarket, London.*
	Royal Society of Victoria, care of the Agent-General for Victoria, *No. 8, Victoria Chambers, Victoria-street, London, S.W.*
MILAN	Royal Lombard Institution of Sciences.
MISSOURI ..	State Survey and University, *Geological Rooms, Columbia, U.S.A.*
MONTREAL ..	Natural History Society.
MUNICH ..	Royal Bavarian Academy of Sciences.
NANCY ..	Society of Sciences.
NEUFCHATEL	Society of Natural Sciences.
NEW HAVEN, U. S. A. ..	Connecticut Academy of Arts and Sciences.
	Editors of Silliman's Journal of Science and Art.
NEW YORK ..	State Museum of Natural History.
	Academy of Sciences, 12, *West 31st-street.*
	American Museum of Natural History, *Central Park, New York.*
OXFORD ..	Bodleian Library.
	Ashmolean Society.
PALERMO ..	Academy of Sciences and Letters.
PARIS	Polytechnic School.
	Geological Society.
	School of Mines.
	Institute of France.
	National Library.
	Jardin des Plantes, Library.
PHILADELPHIA	American Philosophical Society.
	Academy of Natural Sciences, *S W Corner of Nineteenth- and Race-streets.*
PISA	Tuscan Society of Natural Sciences.
PLYMOUTH ..	Plymouth Institution and Devon and Cornwall Natural History.
PRESBURG ..	Association for Natural History.
QUEBEC ..	Literary and Historical Society.
ROME ..	Vatican Library.
	Regia Academia dei Lincei di Roma.
	Societa Italiana delle Scienze (detta dei XL.)
	Royal Geological Society of Italy.
ROUEN	Academy of Sciences.
SAN FRANCISCO	California State Geological Society.
ST. ANDREWS	University Library.
ST. LOUIS ..	Academy of Sciences.
ST. PETERSBURG	Imperial Academy.
	Central Physical Observatory of Russia.
	Imperial Russian Mineralogical Society.
	Geological Committee at the Institute of Mines.
SIDNEY, N. S. WALES ..	The Royal Society of New South Wales, *Sidney.*
STOCKHOLM..	Royal Academy of Sciences, per Longman & Co., *Paternoster-row, London;* and Sampson & Wallis, *Stockholm.*
	Geological Survey of Sweden.
STRASBURG ..	Society of Natural Sciences

STUTTGART ..	Association for Native Natural History.
TORONTO, C.W.	Canadian Institute, care of James Campbell & Son, 33, *St. Bride's, Ludgate Circus, London.*
TOULOUSE ..	Academy of Sciences, Inscriptions, and Literature.
TRURO	Royal Institute of Cornwall.
TURIN	Royal Academy of Sciences.
UPSALA ..	Royal Society of Sciences.
VIENNA ..	Imperial Academy of Sciences.
	The Editor of the "Annual of the Imperial-Royal Geological Institute."
	Imperial-Royal Zoological and Botanical Society, per Braümuller & Co., *Vienna.*
WASHINGTON	Smithsonian Institution Library, per Mr. W. Wesley, 28, *Essex-street, Strand, London.*
WINDSOR ..	Royal Library.
ZURICH ..	Natural History Society.

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